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COLORADO WATER RESOURCES RESEARCH INSTITUTE

Colorado State University
Fort Collins, Colorado

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Natural Resource Economics Division
Economic Research Service
U.S. Department of Agriculture

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The opinions and conclusions contained in this report are solely those of the participants from Colorado State University and from the U. S. Department of Agriculture, Economic Research Service, and do not necessarily represent those of any other person or entity discussed herein.

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CHAPTER I

INTRODUCTION

The demand for water resources is correlated with the developments of civilization. There are many competing water users such as irrigation for agricultural production, direct human consumption, industrial use, mining developments, biological and wildlife requirements, recreation demands, etc. Scarcity of water resources in the United States may someday be an even more critical problem than the scarcity of energy resources.

The Colorado River is a major source of the water supply for the state of Colorado and for several surrounding states. The utilization and development of the Colorado River system directly affects (to varying degrees) Wyoming, Colorado, Utah, Arizona, New Mexico, Nevada and California. The amount of water that can be used by each state has always been in dispute. In 1948, the Upper Colorado River Basin Compact was signed to determine some of the allocations of water quantities. As examples, according to the 1948 Colorado River Basin Compact, the flow of the Yampa River below Maybell, Colorado, must not be reduced below five million acre-feet in any consecutive 10-year period, and the flow of the Colorado River below Lee's Ferry, Arizona, must not be reduced below 50 million acre-feet in any consecutive 10-year period. Although the compact is rather specific on the amount of flows, the direct consequences of the compact on the amount of water available to the State of Colorado is difficult to determine because the amounts of flows from various watersheds fluctuate greatly from year to year.

Thus, the main scope of this study is to investigate the variation of the unutilized water supply from the Yampa River and the effect of the Upper Colorado River Compact on the unutilized supply. The Yampa River was selected because of the compact specifications, the availability of good data, and the presence of several interest groups such as those for irrigation, coal-fired power generation, mining developments, fish ecology, and the recreation demands of Dinosaur National Park. A second river basin, the White River, was also selected for study because of the availability of reliable data, the presence of potential future water demands, and the absolute water rights exceed the mean flows but not the high flows. Many studies have been made on water supplies and demands on these two rivers, but the variability of river flows has never been adequately studied.

The specific topics investigated in this study are: i) institutional constraints; ii) current and future water demands, iii) hydrological analysis on water supplies; iv) relationship between water supplies and demands (including water rights); and v) results, potential implications and possible state actions. Each chapter will focus on one of the topics listed above. However, a certain amount of repetition between chapters will be necessary to show how each topic relates to the overall scope.

A. Brief Description of the Two Rivers

As shown in Figure I-1, the Yampa and White rivers are located in northwestern Colorado. The White River basin encompasses approximately 4,000 square miles and is a tributary of the Green River which is a major tributary of the Colorado River. Currently, the major use of the water is for irrigation of pasture and alfalfa hay; however, due to the

development of coal mining and shale industries, modest expansion has occurred. River flows are heavily concentrated in the months of May and June. During an average water year a flow of 1,853 cubic feet per second (cfs), can satisfy only the water rights decreed prior to 1940, if we assume 100 percent consumption. However, in this region, the most common irrigation practice is flood irrigation; therefore, a substantial amount of the water diverted, returns to the river.

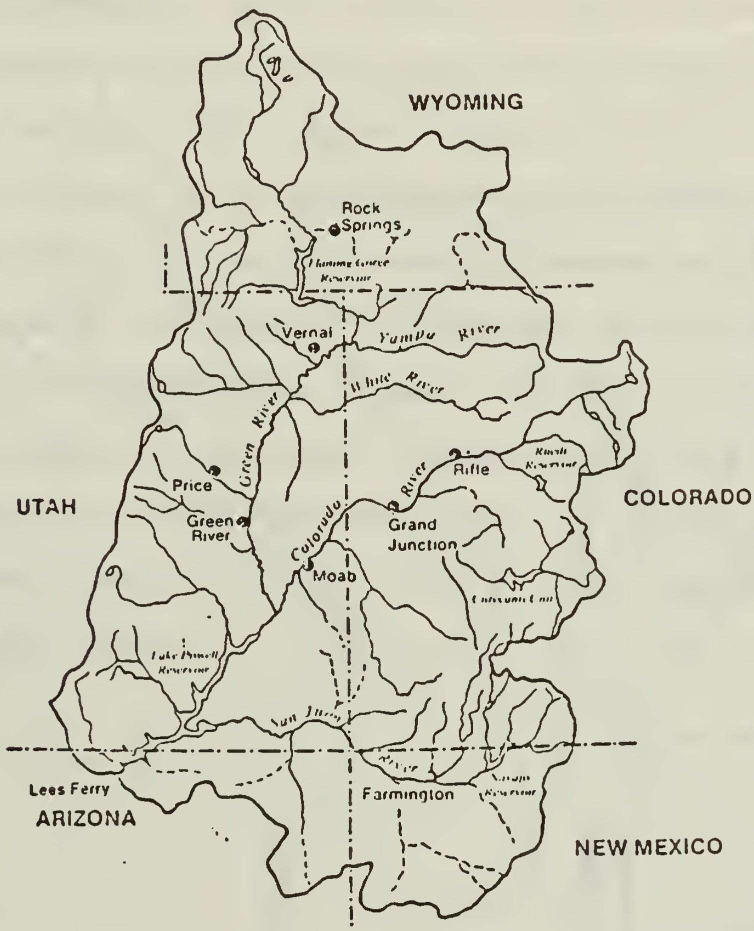

Figure I-1. Location Map (Source: Federal Register, July 6, 1981)

The Yampa River Basin is located north of the White River Basin in northwestern Colorado. Figure I-2 shows the detailed drainage of the

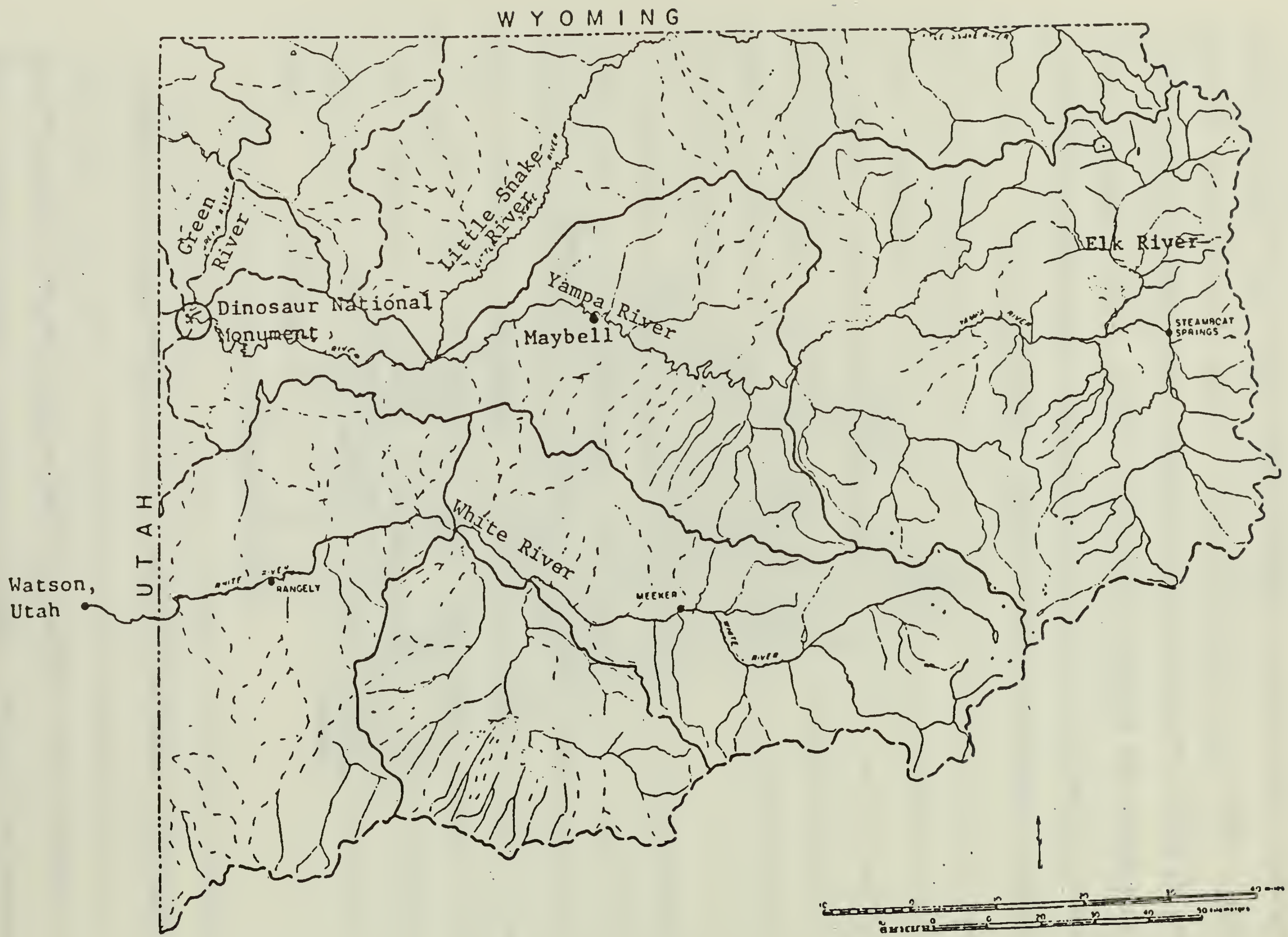

Figure I-2. Drainage Area of the Yampa and White Rivers

two rivers. The Yampa River covers approximately 9,530 square miles and is the largest tributary of the Green River. Dinosaur National Park is situated at the confluence of the Yampa and Green rivers. Irrigation accounts for the principal use of water from the Yampa River. Typically, municipalities draw the water they require from the nearby streams. Steam-electric generation accounts for the only major industrial use of the water. The Yampa River, subject to the regulations of water as required by the Upper Colorado River Basin Compact of 1948, holds six reservoirs to store water for irrigation, fisheries, domestic uses and recreation. Several potential hydro-electric power sites, including the Juniper-Cross Mountain project, have potential for developments. The portion of the Yampa River in Dinosaur National Park is being considered by the National Park Services for inclusion to the National Wild and Scenic Rivers System. Although not part of this study, the instream flow requirements for endangered species such as the Colorado squawfish and the flow requirements for various purposes in Dinosaur National Park and other Federal lands are under active investigations by others.

CHAPTER II

INSTITUTIONAL CONSTRAINTS

I. INTRODUCTION

The utilization of surface water supplies, indeed all water supplies, is controlled by institutional constraints. Broadly speaking, institutions, which are the source of man-imposed constraints, can be defined as "sets of ordered relationships among people which define their rights, exposure to rights of others, privileges and responsibilities."[1/] Within this broad class three levels of institutions can be distinguished: (1) informal institutions including cultural values, mores and religions active in society; (2) formal institutions consisting of laws and regulations; and (3) contractual arrangements used to effect transactions.[2/] This analysis will largely concern institutions on the second level, but references made to compacts between states relate to the third level. By implication, however, the first level will be involved in the analysis because the disparate cultural values, for example, which guide behavior within society stimulate the conflicts which formal institutions attempt to resolve. In the Yampa and the White river basins, not only are there diverse economic values and interests (agriculture and energy), but also conflicts between these economic values and assertions of public environmental values relating primarily to Dinosaur National Monument on the Yampa and endangered

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[1/] Schmid, A. A. "Analytical Institutional Economics: Changing Problems in Economics of Resources for a New Environment," American Journal of Agricultural Economics 54(1972), p. 839.

[2/] Adelman, I. and Head, T. F., "Promising Development for Conceptualizing and Modeling Institutional Change," Working Paper No. 259, Giannini Foundation for Agricultural Economics, April 1983.

species of fish on both rivers. Formal institutions constrain both economic and environmental interests in the achievement of their ends and attempt to resolve their disputes.

The types of formal institutions discussed in this chapter are Coloardo water law, interstate compacts, federal reserved rights, federal regulation of water use, federal land management permits, state and local regulations, and the Colorado Joint Review Process.

II. COLORADO WATER LAW

Water law in Colorado and the other arid western states arose out of the harsh fact that water is scarce relative to demand in normal years, and very scarce in drought years. Thus legal rules establishing rights to the use of water and governing its allocation among right holders is essential. The doctrine of prior appropriation (i.e., first in time is first in right) adopted in various forms by arid western states provides generally as follows:

1. It gives an exclusive right to the first appropriator; and, in accordance with the doctrine of priority, the rights of late appropriators are conditional upon the prior rights of those who have preceded.

2. It makes all rights conditional upon beneficial use--as the doctrine of priority was adopted for protection of the first settlers in time of scarcity, so the doctrine of beneficial use became a protection to later appropriators against wasteful use by those with earlier rights.

3. It permits water to be used on nonriparian lands as well as on riparian lands.

4. It permits diversion regardless of the diminution of the stream.

5. Continuation of the right depends upon beneficial use. The right is lost by nonuse.[3/]

[3/] Huffman, Roy. Irrigation Development and Public Policy (The Ronald Press, New York: 1953) p. 43.

In Colorado, the basic doctrine was embodied in the constitution adopted in 1876, when Colorado became a state. In addition to the above provisions, Colorado water law permits the establishment and trasfer of rights to use water separate from ownership of land, and does not prohibit transbasin diversions. It prioritizes types of beneficial use, but provides that a preferred use (e.g. municipal use over agricultural use) can be enforced only as a right of condemnation.

Water rights on the Yampa River compiled by the State Engineer's Office show total water rights filed through 1970 of 8,921 C.F.S. Only during May and June is the flow of the river in mean years adequate to meet demands equal to all of these water rights. Because of high return flows, more water rights can be served than average flows would indicate. Nonetheless, most irrigation water rights are unable to draw water after July, severely restricting the types of crops that can be grown under irrigation. Although a very high proportion of present water use on the Yampa is for irrigation, some water is for municipal use and for operation of coal-fired electric power plants.

On the White River, Longenbaugh and Wymore (1971) found that absolute decrees on the river claimed 2,800 C.F.S. of flow and conditional decrees claimed an additional 6,000 C.F.S.[4/] These decrees are far above the mean flows for most months; however, return flows allow more rights to be filled than the flow would indicate. Only during the snow melt period are most rights able to withdraw water. During the latter part of the irrigation season only a few irrigation rights have

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[4/] Courts grant absolute decrees when developments necessary to the use of water have been completed and the water is in actual use. Conditional decrees are granted to reserve water pending development and use.

access to stream flow. This fluctuating flow severely restricts the irrigated agriculture of the region even though diversions per acre appear to be quite high, on the order of 8 A.F. per acre. Most of these diversions are for flood irrigation of meadows and pasture early in the year. No water is available for irrigation of most lands once stream flows decline. Hardly any of the water from the White River basin is presently utilized for municipal and industrial purposes.

Undoubtedly options to purchase irrigation water rights or other means of transfer have been made to assure water availability for potential energy developments on the White River and, to a lesser extent, on the Yampa. To be useful in providing water year-round, however, these rights would need to be converted to storage rights. Therefore dams, reservoirs, and diversion structures would be needed. A high proportion of the decrees on the Yampa predate 1938 when Dinosaur National Monument was enlarged to include a portion of the lower reach of the Yampa River in Colorado. This fact could have a substantial bearing on the practical outcome of the federal reserved rights case relating to Dinosaur, but it would not be critical in any case brought under the Endangered Species Act--both types of court cases are discussed below.

In 1973, Colorado enacted an instream flow statute designed to give protection to the natural environment of a stream or lake. The Colorado Water Conservation Board (CWCB) was given the authority to "appropriate in a manner consistent with sections five and six of Article XVI of the State Constitution, or acquire, such waters of natural streams and lakes as may be required to preserve the natural environment to a reasonable degree."[5/] The authority to appropriate water given to the CWCB by this

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[5/] Colorado Revised Statutes 37-92-102, sec. 3.

statute would grant rights junior to many established rights. However, as a junior appropriator, the CWCB could resist any changes in points of diversion or use by senior appropriators which could materially injure or affect the board's rights.[6/] Rights acquired by purchase or gift would continue the time of right of the original appropriation. So far, the CWCB has made minimum flow water right claims on a number of small creeks that feed the Yampa and White rivers, but not on these rivers themselves or their principal tributaries.

III. INTERSTATE COMPACTS

States are expected to govern the excercise of water rights within their boundaries in such a way as to meet their obligations under interstate compacts to which they are a party.

Colorado is a party to the Colorado River Compact of 1922. The most important provisions of the compact are as follows:

> "1. The Colorado River basin was divided into an upper basin, with the line of demarcation at Lee's Ferry, Arizona. Here the waters of the entire upper basin system...converge into one system.
>
> "2. The annual beneficial consumptive use of 7.5 million acre-feet of water was appointed to each sub-basin with the lower basin granted the right to use another million acre-feet annually if it was available.
>
> "3. States of the basin were aligned into two divisions. The upper basin states included Colorado, Wyoming, Utah and New Mexico. The lower basin states were California, Arizona, and Nevada.
>
> "4. The upper basin states were not to cause the flow of the Colorado at Lee's Ferry to be less than 75 million acre-feet in any period of ten consecutive years.[7/]

[6/] Green V. Chaffee Delta Co. 371 P2d., 775 (1962).

[7/] Goslin, Ival, "Colorado River Development," in Values and Choices in Development of the Colorado River Basin (University of Arizona Press, Tucson: 1978) p. 30.

The historic virgin flows of the river prior to 1922 had been taken to be 15 million acre-feet per year. Since that time the virgin flows have averaged 13.8 million acre-feet per year.

For a detailed discussion of the implications of this lower flow on water consumption in the upper basin and in Colorado see The Upper Colorado River Basin and Colorado's Water Interests, published by the Colorado Forum in 1982.

The implications, if any, of this analysis of the variability of the unutilized surface water supplies of the Yampa and White river basins with respect to the provisions of the 1922 compact (or the treaty with Mexico of 1944) are outside the scope of this study.

In 1948 the states of the upper basin signed the Upper Colorado River Basin Compact. This compact apportioned the waters of the Colorado as follows: Colorado 51.75 percent, New Mexico 11.25 percent, Utah 23 percent and Wyoming 14 percent. Two articles of the compact, which have important bearing on the Yampa River, are Article XI and XIII. Article XI governs the Little Snake River, a tributary of the Yampa. Important sections include:

> 2. Water diverted from the main stem of the Little Snake River below a point one hundred feet below the confluence of Savery Creek and the Little Snake shall be administered on the basis of an interstate priority schedule prepared by the Upper Colorado River Commission in conformity with priority dates established by the laws of the respective states.
>
> 2d. The states of Colorado and Wyoming each assent to diversions and storage of water in one state for use in the other state subject to compliance with Article IX of this compact."[8/]

The states also agreed to share equally water curtailment in dry years.

Article XIII places restrictions on Colorado's use of the Yampa. Somewhat similar to the Colorado River Compact, it provides that

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[8/] Colorado Revised Statues 37-62-101.

Colorado will not cause the flow of the Yampa at Maybell, Colorado to fall below five million acre feet during any consecutive ten-year period.

Neither Article XI nor Article XIII has been a substantial constraint so far on consumptive use of water in Colorado. Later in this report, the results of testing whether possible projected uses of water would be constrained by Article XIII will be examined.

No compact provision nor federal judicial decree relates to the White River as it enters Utah. As consumptive use of water in Colorado increases on the White River, it can be expected that Utah will endeavor to obtain security for its own water use by means of compact or federal judicial decree.

IV. FEDERAL RESERVE RIGHTS

The doctrine of federal reserved rights has recently come to have important potential consequences for water demands on the Yampa River. Federal reserved rights are a judicially created doctrine. By this it is meant that nowhere in specific statutory law has the definition of reserved rights been given. Rather, it has come to be defined through a series of court decisions which have given it substance.

Norman Wengert of Colorado State University points to three general facts to remember about federal water rights in general. In his words:

> "It is important to recognize, first, that the primary basis for the reserved rights doctrine lies in federal sovereign ownership and the power to manage Federal property--concepts stemming from the original cessation of territory in the semi-arid and arid west to the United States by previous sovereigns. These Reserved Rights rest not simply on rights derived from use, constrained by an obligation not to harm downstream interests, as would be the case if Federal rights were derived from Common Law Riparian Doctrines.

> Second, it must be recognized that Federal rights in water have never been and cannot be subjected to state jurisdiction without explicit consent of the Federal Government.
>
> Third, the rights of the Federal Government are not qualified by 'first in time, first in right,' nor by 'use it or lose it' principles."[9/]

The doctrine of reserved rights received its first exposition in Winters v. U.S. (207 U.S. 564). This case decided on 1908, revolved around the rights of the Indians living on the Fort Belknap Reservation to be protected from dams on the Milk River in Montana which would have adverse effects on their use of water on the reservation. The United States argued that it had a right to all the waters of the river to fulfill the purposes for which the reservation was created. In this case, the purposes were seen as civilization and improvement of the Indians' conditions through the development of agriculture. Thus, as Wengert says, the Supreme Court "initiated the doctrine that the act of reservation of lands (withdrawn from the public domain) established a water right from the date--not requiring use, unlimited in quantity except as reasonably related to the purposes of the reservation.[10/] Until later cases, however, it appeared that reserved rights were to apply only to Indian reservations.

In Arizona v. California (373 U.S. 546) the Supreme Court held in 1963 that the principle of reserving water rights for Indian reservations was also applicable to other federal reservations. The court included in its definition of other reservations Lake Mead National Recreation Area, the Havasu Lake National Wildlife Refuge, the Imperial National Wildlife Refuge, and the Gila National Forest.

[9/] Wengert, Norman, The Purposes of the National Forests--A Historical Reinterpretation of Policy Development (Completion Report of Research, Colorado State University, Fort Collins: 1979, Appendix A, p. A-3.)

[10/] Ibid, p. A-3.

The application of federal reserved rights to non-Indian reservations was further set forth during 1976 in Cappaert v. U.S. (426 U.S. 128). In the words of the Court:

> "...when the Federal Government withdraws its lands from the public domain and reserves it for a federal purpose, the Government, by implication, reserves appurtenant water then unappropriated to the extent needed to accomplish the purpose of the reservation. In doing so the United States acquires a reserved water right in unappropriated water which vests on the date of the reservation and is superior to the rights of future appropriators."[11/]

Reservation of water is empowered by the Commerce Clause, Art. I, sec. 8, which permits regulation of navigable streams, and the Property Clause Art. IV, sec. 3, which permits federal regulation of federal lands. The doctrine applies to Indian reservations and other federal reservations, encompassing water rights in navigable and non-navigable streams. The Cappaert case still left one vital question unanswered. What was the "purpose" of a federal reservation?

U.S. v. New Mexico (438 U.S. 696), decided in 1978, focused on the question of the purpose of a national forest. The 1978 Organic Act set forth the purposes of the forests: "to improve and protect the forest within the boundaries, or for the purpose of securing favorable conditions of water flow, and to furnish a continuous supply of timber for the use and necessities of citizens of the United States."[12/] The United States argued that certain instream flows were needed for environmental, recreational, or wildlife preservation uses. But as Harold Ranquist said:

[11/] Cappaert v. United States, 426 U.S. 128 or 48L Ed. 2d 523, p. 525.

[12/] 16 U.S.C. 475.

> "...the majority, adopting a narrow definition of the primary purpose of Congress in creating national forests, held that instream flows for recreation, fish and wildlife, and environmental uses were necessary only to fulfill the secondary purposes of Congress, and that the United States would be required to comply with the provisions of state law to obtain water rights for the fulfillment of such secondary purposes."[13/]

Certain scholars have argued against this narrow construction of the federal reserved right because of certain consequences:

> "...now, in effect, all private water rights under the appropriation doctrine have become vested vis-a-vis National Forest reservations on application of state concepts of 'use it or lose it' and 'first in time, first in right.' No reversal of the Court's narrow interpretation of National Forest purposes would change the situation.... This could not change even if at some later time another court would modify the holding, because property rights as protected by the fifth amendment would then come into play."[14/]

How possibly does the doctrine of federal reserved rights affect the Yampa River?

The Yampa, as of 1938, passes through an enlarged Dinosaur National Monument near the Utah border. What are the purposes of national parks and monuments?

In U.S. v. City and County of Denver (Colo., 656 p. 2d 18), the Colorado Supreme Court during 1982 considered water rights for national parks and monuments as well as national forests. The court reviewed the development of the reserved rights doctrine in the cases mentioned above, as well as some others. It then set up three conditions for a reserved right:

[13/] Ranquist, Harold A., The Winters Doctrine and How It Grew: Federal Reservation of Rights to the Use of Water. (Brigham Young Law Review: 1975) p. 269.

[14/] Wengert, op. cit. pp. A7-H-8.

1. A determination of the precise purpose to be served.

2. Frustration of the purpose without water.

3. Quantification of the minimum amount of water required to fulfill the purpose.

In this case the United States argued that one of the purposes of a national monument was recreation. Hence, it argued that some reservation of water for recreational boating was proper. The court did not accept this, asserting that the 1906 Antiquities Act, which established the purposes of a national monument showed these purposes to be primarily scientific and historic.[15/] The court also rejected the argument that the 1916 National Park Service Act, which placed most monuments under the administration of the Park Service, broadened the purpose of a monument. But, in considering the Colorado water court decision, which came to the Supreme Court on appeal, the court said:

> The water court expressed a willingness to grant some stream flows for the purpose of preserving fish habitats of historic and scientific interest.... In our view, the relevant reservation document is the presidential proclamation of 1938 which enlarged Dinosaur to protect "objects of historic and scientific interest." However, the water court was correct in ordering the master-referee to determine whether the 1938 proclamation intended to reserve water for fish habitats of endangered species of historic and scientific interest, and if so, to quantify the minimal amount of water necessary to fulfill that purpose. We therefore remand to the water court for further proceedings on the issue of fish habitats.[16/]

The Colorado Supreme Court also noted:

> "Dinosaur National Monument is located at the lowest reaches of the Yampa River in Colorado.... To find a reserved right to instream flow that far downstream would <u>have a significant impact on numerous upstream users</u>. (emphasis added).... Moreover, awarding the United States minimum flow rights would

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[15/] Colo. 656 P. 2d p. 27.

[16/] Ibid, p. 29.

result in deliveries of water by Colorado to Utah in excess of the obligation specified in the Upper Colorado River Compact."[17/]

If a federal instream flow right is granted, this right would have to compete for water within the state appropriative system which would give it a water priority date of 1938, junior to a large proportion of the present decrees in the river, as already noted above.

Although the Colorado Supreme Court has referred the case back to the Colorado water court, the case also has been appealed by both the Denver Water Board and the U.S. Attorney General within the federal court system.

The Colorado Supreme Court also noted in this case that: "Holders of decreed and conditional water rights cannot plan or develop sizable water projects until they are certain of the extent of the federal government's claim."[18/] Thus, the federal government, in addition to proving satisfactorily that the 1938 proclamation enlarging Dinosaur intended to reserve water for fish habitats of endangered species of historic or scientific interest, must quantify the amount of water needed to fulfill this intended purpose. The National Park Service, assisted by other federal agencies, is in the process of determining its proposed instream flow right to present to the Colorado Water Court.

Clearly, no early final decision with respect to the application of federal reserved rights to Dinosaur National Monument can be expected. Even if the federal government finally loses this case, it should be noted that the same substantive issue, protection of endangered species

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17/ Ibid, p. 27, note 44.

18/ Ibid, p. 30.

of fish, could arise again, as will be discussed below, under the Endangered Species Act of 1973, as amended.

V. FEDERAL REGULATION - COMPREHENSIVE

Through Section 404 of the Clean Water Act the federal government adopted a comprehensive regulatory strategy to assure that nonfederal economic developments are consistent with federal conceptions of environmental propriety.[19/] To assure complete jurisdiction, the Congress adopted (and the federal courts have not yet found unconstitutional) a provision that "all waters of the United States" are subject to regulation under the Act. Specifically, under Section 404, "wetlands" are included.

In this connection, the Army Corps of Engineers is given authority to regulate the discharge of dredged and filled materials into the waters of the United States. The regulatory process in simplified form is as follows:

1. Corps receives application for a permit.

2. District Engineer performs technical analysis or proposal impacts and refers applications to state and local governments and other federal agencies for analysis and recommendations.

   (a) Engineer can provide for conditions to minimize or offset adverse impacts.

   (b) Process can involve either an environmental assessment or an environmental impact statement in accordance with the National Environmental Policy Act.

   (c) "All factors which may be relevant to the proposal must be considered including the accumulative affects thereof: among those are conservation, economics, aesthetics, general environmental concerns, wetlands, cultural values, fish and wildlife values, flood hazards, land use, navigation, shore erosion and accretion, recreation, water supply and conservation, water quality, energy needs, safety, food and fiber production, mineral needs, consideration of private ownership, and, in general, the needs and welfare of the people."

19/ P.L. 92-500 of 1972 as amended by P.L. 95-217 of 1977.

3. Permit will be granted, "unless its issuance is found to be contrary to the public interest."[20/]

Many of the above environmental factors would be present potentially if any dams or other diversion structures were built or operated on the Yampa and White Rivers or their tributaries. The most constraining impact would appear to be, at present, the impact on endangered species of fish as determined in accordance with the Endangered Species Act of 1973, as amended.[21/]

This act requires that all federal agencies must ensure that activities authorized by them will not threaten the continual existence of endangered or threatened species or destroy or modify cultural habitats. Procedurally, the Secretary of the Interior can issue specific regulations to conserve and protect endangered species. Also, the Secretary determines, through a listing in the Code of Federal Regulations, which species are endangered or threatened. In matters concerning section 404 permits and the Endangered Species Act, the Secretary of the Interior has the final administrative veto power over the Secretary of the Army.

Currently, three types of fish have been placed on the endangered species list, which are involved with the White and Yampa rivers.[22/]

[20/] Quotations are from proposed rules of the Army Corps of Engineers in Federal Register Vol. 48, No. 93, May 12, 1983, p. 21469. Final rules were not published as of June 28, 1984. However, informal staff advice from the Army Corps of Engineers indicates that the quoted sections are not likely to be substantially changed in the final rules, because the language is consistant with a related consent decree.

[21/] 16 U.S.C. 1531.

[22/] CFR sec. 17.11, "White River Fishes Study, Final Report, U.S. Fish and Wildlife Service (Salt Lake City, 1982).

These are the Colorado squawfish, the humpback chub and the bony-tailed chub. The U.S. Fish and Wildlife Service has conducted river-fishes studies on the White and Yampa Rivers. The most significant conclusions focused on the squawfish. For the White River, the service found that:

> "...several projects (in water resources development) appear to pose problems for endangered fishes. Results of Colorado River Fishery Project studies in the Upper Colorado River basin indicate the endangered Colorado squawfish has a complicated life history.... It is, therefore, recommended that the White River not be fragmented by separate subbasin development but that a basin-wide fishery management plan be developed in order to ensure the survival of this species."[23/]

The Yampa was found to be even more important to the survival of the squawfish, to the point of being cited as the potential key to the survival of the fish. Again, the Fish and Wildlife Service called for a "basin-wide fishery management plan to be developed and implemented to assure the survival of the species," before further water resources development occurs.[24/]

During the summer of 1984, a memorandum of understanding was signed to seek ways "to develop and implement a program of reasonable and prudent alternatives which will enable Federal agency actions associated with water development and depletions in the Upper Basin of the Colorado River to proceed pursuit to Section 7 of the Endangered Species Act." The memorandum was signed by regional directors of the U.S. Fish and Wildlife Service and the Bureau of Reclamation and by the chief natural resources offices of the states of Colorado, Utah and Wyoming. In addition, an appropriation of some $450,000 was being sought from the Congress to fund the joint effort. The aim of the effort is to avoid

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23/ "Yampa River Fishes Study, Final Report," U.S. Fish and Wildlife Service (Salt Lake City, 1982), p. 75.

24/ Ibid.

"jeopardizing the continued existence of any threatened or endangered fishes, while fully acknowledging and considering the beneficial uses of water pursuant to the respective state water rights systems and the use of water apportioned to a state pursuant to the compacts concerning the waters of the Colorado River."

In a related matter in Colorado, but outside the Colorado River Basin, the U.S. District Court has acted on a case involving both the Endangered Species Act and the Clean Water Act. The issue was whether the Army Corps of Engineers had acted correctly in denying a nationwide 404 permit to Riverside Irrigation District and the Public Service Company of Colorado.[25/] The reason the permit was denied was because it was found that the operation (i.e. water storage) of the dam would have an adverse impact on the habitat of the whooping crane two hundred miles downriver. The Army Corps of Engineers had, in accordance with the Endangered Species Act, consulted with the Fish and Wildlife Service regarding the potential impact on the whooping crane. The Fish and Wildlife Service had found that there would be an impact. Thus, the Corps denied the nationwide permit and required an individual permit with full public interest review. In the words of the court:

> "Because the Clean Water Act allows federal agencies to consider deleterious downstream environmental effects from a project and because the Endangered Species Act requires federal agencies to take whatever measures are necessary, within their authority, to protect an endangered species and

[25/] U.S. District Court for the District of Colorado, Civil Action Riverside Irrigation District and Public Service Company of Colorado vs. Colonel William R. Andrews, District Engineer, U.S. Army Corps of Engineers, Omaha District, No. 80-k-624, July 31, 1983. Nationwide permits cover a group of activities throughout the United States which involve dredging and filling, but whose impact is assumed to be minimal as a separate activity, or as a group of activities.

> its habitat, the defendant in this case was required to halt the plaintiffs from proceeding under the nationwide permit when their project had the potential of adversely affecting the whoopers and their habitat downstream from the project.[26/]

The courts also addressed the issue of interference with the South Platte Compact and state water rights. It found that the Clean Water Act was a clear grant of jurisdiction which simply put restrictions on the exercise of state water rights, but did not affect the rights themselves. Regarding the compact, the court found that a nationally applicable law was enforceable even if it did affect a prior compact.

This case is in the process of appeal. However, should a decision closely paralleling this district court decision be rendered by a higher court, then those who seek to construct storage reservoirs (e.g., on the Yampa and White rivers and their tributaries) will have to be aware that a depletion of water could be seen as an impact harmful to downstream endangered and threatened species. Thus the Endangered Species Act of 1973 could be a serious constraint upon their developmental activites.

The National Environmental Policy Act (NEPA) also can be viewed as a comprehensive, regulatory statute which has come to have a bearing on many federal actions which affect the environment.[27/] The most important section of the statute is section 102, which provides for the preparation of environmental impact statements. This section requires that all federal agencies include in "every recommendation or report or proposal for legislation and other major federal actions significantly affecting the quality of the human environment a detailed statement on:

[26/] Ibid.

[27/] 42 U.S.C. 4321.

1) the environmental impact of the proposed action; 2) any adverse environmental effects which cannot be avoided should the proposal be implemented; and 3) alternatives to the proposed action." It is important to note that NEPA centers on "federal actions" which mean projects developed with federal funds or subject to federal regulation (e.g., section 404 of the Clean Water Act). NEPA, however, contains no substantive compliance standards to constrain action. Its procedures can cause substantial delay. Thus compromise with assertions of environmental values can be preferable to delay.

VI. OTHER FEDERAL REGULATION - SPECIFIC TYPES

Brief reference should be made to other federal regulatory activities that could constrain water resource developments on the Yampa and White rivers.

The Wild and Scenic Rivers Act provides that no federal agency can "assist by loan, grant, license or otherwise in the construction of a water resources project that could have a direct and adverse effect on the values" for which a river was so designated under the act.[28/] Developments can occur above or below such a designated river if the area is not invaded or its values diminished.

At the present time a proposal exists which recommends the inclusion of a major tributary of the Yampa, the Elk River, in the national wild and scenic river system. Specifically the proposal recommends designation as a wild river, 17 miles of the upper North Fork and the entire South Fork, and 12 miles of the upper main stem, Middle Fork,

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[28/] 16 U.C.S. 1278.

and lower North Fork. This proposed designation leaves available a reservoir development site at Himan Park, but otherwise would preclude development in the designated area. So far, this proposal is only a recommendation to Congress that the Elk be included in the Wild and Scenic Rivers system. Congress must approve before designation can be made.

The Fish and Wildlife Coordination Act provides for a comprehensive integration of fish and wildlife conservation with federal water resources development. The act's statement of purpose says "wildlife conservation shall receive equal consideration and be coordinated with other features of water-resources development programs through the effectual and harmonious planning, development, maintenance, and coordination of wildlife conservation and rehabilitation..." The act requires that all federal agencies which license, construct or operate water control projects must make adequate provision for the management, conservation, and maintenance of the wildlife resources contained within the project. In simpler terms this statute is an acknowledgment that water resources development projects must take wildlife concerns into account in planning and development. Also, the granting of permits by the Army Corps of Engineers under section 404 of the Clean Water Act, discussed above, is subject to the provisions of the Fish and Wildlife Coordination Act.

The National Historic Preservation Act of 1966 requires that federally initiated or funded "undertakings" shall take into account the "effect of the undertaking on any district, site, building, structure, or object that is included in or eligible for inclusion in the National

Register of Historic Places.[29/] The Preservation of Historical and Archeological Data Act requires that, prior to the construction or the licensing of construction of a dam, a federal agency must give written notice to the Secretary of the Interior as to the site of the proposed dam and the area to be flooded.[30/] The Secretary can then take action to protect the features before the project begins.

U.S. Forest Service. Special use authorizations cover all uses and occupancy of federal forest lands. These authorizations could involve, among other things, the exercise of mining rights, the need to gain access to mining claims across Forest Service land, and the construction of dams or reservoirs. When an application for a special use authorization is received, the Forest Service will conduct an environmental analysis to see if an environmental impact statement is required. Conditions included in authorizations could substantially constrain development.

Bureau of Land Management. The Bureau of Land Management of the Department of the Interior has an extensive list of permits that are required regarding possible resource development on the lands it manages. These permits include, but are not limited to, oil and gas exploration, oil and gas leasing, coal exploration and leasing, oil shale leasing and procedures for the sale of federal public lands. It, too, will conduct an environmental analysis to determine whether an environmental impact statement is required and its permits can contain restrictions that might constrain development.

[29/] 16 U.S.C. 469.

[30/] 16 U.S.C. 469 and 470.

VII. STATE AND COUNTY REGULATIONS

Colorado requires resource developments to comply with several different types of regulations before developments can proceed. These include:

1. State land permits where state-owned lands are involved,
2. Strip-mine regulations,
3. Water quality regulations,
4. Air quality regulations,
5. Dam safety regulations.

Counties in the White and Yampa drainages require permits which can include conditions that constrain resource development:

<u>Garfield County</u>. Special Use Permit. Required on private lands where extraction and processing are allowed by zone district. Also required for some on public lands where no state or federal permit or contract regulates. A Conditional Use Permit is required for use where contract or permit from state or federal authority authorizes the use.

<u>Moffat County</u>. Conditional Use Permit. All mineral and extractive uses, as well as processing plants and transportation facilities require a conditional use permit.

<u>Rio Blanco County</u>. Special Use Permit. Required for all mineral exploratory and extractive uses.

<u>Routt County</u>. Special Use Permit. Required for energy or mineral development outside county designated mining district.

<u>Other county and local land use legislation</u>. Certain Colorado statutes also give counties and localities the authority to regulate land use in their areas.

1. The Colorado Land Use Act of 1974. Gives local govenments the power to regulate and administer areas and activities of state interest. Areas include mineral resource areas, areas of historic, natural and cultural resources. Activities include the development of water and sewage treatment systems.
2. Local Government Land Use Control Enabling Act of 1974. Gives local government the power to plan, regulate and administer land use. One specific authority allows the localities to protect land from activity that might adversely affect wildlife.

VIII. COLORADO JOINT REVIEW PROCESS

The Colorado Joint Review Process (CJRP) is an intergovernmental review which attempts to coordinate the permits, licenses, etc. required by various levels of governmental agencies--federal, state and local. This coordinated review process, which is voluntary on the part of the resource developer, is designed to speed up the regulatory process and avoid unnecessary duplication. In May of 1983 the CJRP was officially designated by the legislature as the official process by which the coordination will occur. The CJRP is a function of the Colorado Department of Natural Resources. As of September 1984, there were no projects under the CJRP for the White and Yampa River basins.[31/]

IX. CONCLUSIONS

The institutional constraints on potential water and related resource developments in the Yampa and White river basins, involving all

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[31/] Communication from Adam Poe, Director, Colorado Joint Review Process.

three levels of government are substantially varied and complex. Regulations at all three levels relating to energy developments themselves (e.g., coal, oil shale, mining) can be presumed, so far as this report is concerned, to be capable of being met by additional investments necessary to comply. But the legal feasibility of related water resource developments within the basins, and transbasin diversions out of the basins as contemplated by the Denver Water Board, is not yet clear. The federal reserved rights case involving Dinosaur National Monument must be decided in one way or another. Moreover, a separate case under the Endangered Species Act of 1973 could also be filed, if necessary, and this case could also take years to decide. But the joint Federal-State study, concerning which agreement was reached in the summer of 1984 that was discussed above, could lead to a solution that would avoid such confrontation.

The chapters which follow provide information on the variability of unutilized surface water supplies for the Yampa and White River basins assuming three different levels of future economic (largely energy) development and the consequent additional consumptive use of water. On this basis, it will be concluded whether or not Colorado could continue to comply with the Upper Colorado River Compact and how much water would continue to flow through Dinosaur National Monument and be available for the preservation of endangered species of fish in these rivers.

CHAPTER III

CURRENT AND FUTURE WATER DEMANDS

I. EXISTING WATER USE

The major current water use in the Yampa River and the White River basins is for irrigation of crops, hay land and pastures. These uses constitute 83 to 95 percent of the total diversion and consumptive use. Most of the irrigated lands are located along streams and rivers. The water is delivered through irrigation canals. Figure III-1 shows the location and extent of agricultural lands on the two basins. Irrigation diversions occur between the months of May and October with the peak demand in July. (For more information on irrigated agriculture on the White and Yampa river basins, see Appendix A). Other water uses in the basin include municipal and industrial water supplies and transmountain diversions.

Assembling water diversion data is a time-consuming task. Daily diversion records of every ditch in the basin must be compiled. Appendix B shows water supply and use for the Yampa, Little Snake and White river basins as compiled by Water Division Six of the State Engineer's Office for 1972, 1973 and 1974.

For the Yampa River basin, records of consumptive use by various categories for the years 1976 through 1981 are shown in Table III-1. For the White River, consumptive use for the various sectors for the period 1976 through 1981 is shown in Table III-2. These data are compiled from river commissioner reports that are prepared annually for the State Engineer's Office. (The Yampa River outflow is the estimated flow above the confluence with the Little Snake River.) The data

Table III-1. Annual Consumptive Use of Water (acre-feet) for the Yampa River Basin Between 1976 and 1981[1]

	YEAR					
	1976	1977	1978	1979	1980	1981
			Acre-feet			
Irrigaton	94,094	65,002	95,160	101,263	101,156	51,853
Reservoir Evaporation	6,810	6,248	8,958	9,422	8,811	4,617
Change in Storage	-8,948	-125	16,220	399	-1,465	1,846
Municipal/ Industrial	7,100	6,200	6,900	9,900	11,800	14,800
Trans. Mtn. Diversion	2,395	856	4,111	2,930	3,389	1,345
Misc.	16,950	650	800	800	800	700
Total	118,401	78,832	132,148	124,714	124,491	75,161
Measured Outflow	826,298	358,200	1,464,900	1,321,788	1,307,000	565,050
Basin Yield	944,699	437,032	1,597,048	1,446,502	1,431,491	640,211
Pct. Consumed	12.5%	18.03%	8.27%	8.62%	8.70%	11.74%

[1]Source: Colorado State Department of Water Resources, Division 6, 1982.

Table III-2. Annual Consumptive Use of Water (acre-feet) for the White River Basin Between 1976 and 1981[1]

	YEAR					
	1976	1977	1978	1979	1980	1981
			Acre-feet			
Irrigation	41,224	33,934	39,214	38,782	36,983	27,193
Reservoir Evaporation	1,170	1,322	1,178	1,140	1,120	662
Change in Storage	-1,660	-147	-148	-76	123	97
Municipal/ Industrial	6,223	5,500	6,300	3,500	4,200	4,000
Trans. Mtn. Diversion	0	0	0	0	0	0
Misc.	500	400	500	500	500	400
Total	47,477	41,010	47,044	43,846	42,926	32,352
Measured Outflow	457,740	223,100	529,000	556,000	526,500	337,200
Basin Yield	505,198	264,110	576,044	599,846	569,426	369,552
Pct. Consumed	9.39%	15.52%	8.17%	7.31%	7.54%	8.75%

[1]Source: Colorado State Department of Water Resources, Division 6, 1982.

indicate that the annual consumptive use in the Yampa River and the White River basins is about 8 percent of the basin yield during wet years and ranges from 12 to 18 percent during dry years. The percentage of water consumed rises in dry years due to higher ET and a higher proportion of flow diverted for use in the basin.

In this study, the existing total water use for each month is calculated by averaging the actual total consumptive water use for the corresponding years between 1970 and 1980. In a separate study it was determined that there were no significant changes in water use between years in the period between 1970 and 1980. (See Tables III-3 and III-4 for an average of consumptive water use on the two basins for the years between 1970 and 1980.)

At the present time, transbasin diversion of water from the Yampa River basin is minimal relative to the total surface water available. Several potential reservoir projects have been proposed which will capture part of the peak runoff and will provide water for irrigation and other uses. There is a projected increase in consumptive use of water for irrigation as well as industrial development in the future; hence further competition among water users for the limited water resources is inevitable. The availability of water for the various uses is determined largely by ownership and use of water rights, and availability and use of reservoir storage capacity; as well as by the interstate and regional water compacts established for the whole Colorado River Basin.

II. PROJECTED WATER DEMANDS

Projections of future water demands in the two study basins are required to assess water availability for addition uses. Accurate

Table III-3. Average Consumptive Water Use by Months for the Yampa River Basin, Colorado, 1970-1980.

Month											
Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
Acre-feet											
10,750	1,170	1,170	1,170	1,170	1,170	1,231	19,113	23,689	35,099	25,735	18,868

Table III-4. Average Consumptive Water Use by Months for the White River Basin, Colorado, 1970-1980.

Month											
Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
Acre-feet											
3,682	448	448	448	448	448	460	6,349	7,922	11,848	8,501	6,299

projections are impossible to make; therefore, it is best to examine a range of future demands. For this study, we have used the potential average annual diversions for the year 2000 as developed for the Upper Colorado River Basin by the Colorado Department of Natural Resources in 1979. These withdrawal estimates represent combinations of three possible levels of overall economic growth in the region, referred to as "low, medium, and high" and three levels of oil shale and coal development, referred to as "without" (i.e., no energy development), "baseline" (some energy), and "accelerated" (fast development) for the year 2000. Using combinations of the above classifications, nine scenarios of growth and development were created. These scenarios were used to predict possible levels of future water demand.

The projected annual water demands for the three levels of economic growth are shown in Table III-5. The projected additional monthly water demand is shown for the Yampa River in Table III-6, and for the White River in Table III-7. The following assumptions were made in the energy development water requirements:

For the Yampa River Basin, no synthetic fuel development was included in the baseline case, and a single high BTU coal gasification facility was assumed in the accelerated case. Most likely, such a plant would be located in the vicinity of Craig, Colorado.

In the White River Basin, oil shale development in the vicinity of Piceance Creek Basin accounts for all of the projected energy development. However, in 1984, with the current demand for oil, several of the oil shale companies have no immediate plan to develop oil shale projects. The only active oil shale project is being conducted by Union Oil Company. Even the status of the government sponsored synthetic oil

Table III-5. Projected Annual Water Demands for the Yampa and White River Basins in the Year 2000 for Three Potential Levels of Economic Growth, No Energy Development

Basin	Growth rate	Water Use: Thermal power	Irrigation	Fish and wildlife	Mineral extraction	Municipal/ industrial	Totals
				Acre-feet			
Yampa River	Existing	7,000	80,000	6,000	1,000	2,000	96,000
	Low	31,000	80,000	7,000	1,000	2,000	121,000
	Medium	37,000	84,000	8,000	3,000	4,000	136,000
	High	37,000	90,000	8,000	4,000	4,000	143,000
White River	Existing	0	37,000	2,000	3,000	1,000	43,000
	Low	8,000	37,000	2,000	3,000	1,000	51,000
	Medium	10,000	37,000	2,000	5,000	4,000	58,000
	High	10,000	45,000	3,000	5,000	4,000	67,000

Source: Colorado Department of Natural Resources, 1979.

Table III-6. Projected Additional Monthly Water Demand for the Yampa Basin in the Year 2000 for Nine Combinations of Potential Economic Growth and Energy Development

Level of Development[1]	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.
						1000 Acre-feet						
LWO/LWB	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08
LWA	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
MWO/MWB	3.30	3.00	3.00	3.00	3.00	3.00	3.00	3.60	3.70	4.10	3.80	3.50
MWA	4.20	3.90	3.90	3.90	3.90	3.90	3.90	4.50	4.60	5.00	4.70	4.40
HWO/HWB	3.80	3.10	3.10	3.10	3.10	3.10	3.10	4.50	4.90	5.90	5.00	4.40
HWA	4.70	4.00	4.00	4.00	4.00	4.00	4.00	5.40	5.80	6.80	5.90	5.30

[1]LWO, MWO, and HWO refer to: low, medium, and high "without energy development" scenarios.
LWB, MWB, and HWB refer to: low, medium, and high "with baseline energy" scenarios.
LWA, MWA, and HWA refer to: low, medium, and high "with accelerated energy" scenarios.

Source: Colorado Department of Natural Resources, 1979.

Table III-7. Projected Additional Monthly Water Demand for the White Basin in the Year 2000 for Nine Combinations of Potential Economic Growth and Energy Development

Level of Development[1]	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.
						1000 Acre-feet						
LWO	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
LWB	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2
LWA	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0
MWO	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3
MWB	8.8	8.8	8.8	8.8	8.8	8.8	8.8	8.8	8.8	8.8	8.8	8.8
MWA	15.6	15.6	15.6	15.6	15.6	15.6	15.6	15.6	15.6	15.6	15.6	15.6
HWO	1.89	1.33	1.33	1.33	1.33	1.33	1.33	2.5	2.8	3.57	2.88	2.37
HWB	9.5	8.9	8.9	8.9	8.9	8.9	8.9	10.0	10.3	11.1	10.4	9.9
HWA	16.3	15.7	15.7	15.7	15.7	15.7	15.7	16.8	17.1	17.9	17.2	16.7

[1]LWO, MWO, and WHO refer to: low, medium, and high "without energy development" scenarios.
LWB, MWB, and HWB refer to: low, medium, and high "with baseline energy" scenarios.
LWA, MWA, and HWA refer to: low, medium, and high "with accelerated energy" scenarios.

Source: Colorado Department of Natural Resources, 1979.

corporation is not clear. Thus, whether significant quantities of water will in fact be demanded for oil shale production is uncertain at this time.

The quantity of water that would be required to process oil shale is also highly uncertain. In general, a range from 3,000 acre-feet per year to 9,000 acre-feet per year per unit sized (50,000 barrels/day) plant have been presented. A value of 5,700 acre-feet per year was selected in the basin 13(a) study as a reasonable estimate. Table III-8 contains the estimated water supplies necessary for the baseline and accelerated scenarios in the two basins.

Based on the above estimates, total annual water withdrawals for each basin for the nine possible scenarios were estimated. These are shown in Table III-9.

Because the river flows are highly seasonal, an examination of water availability on a monthly basis is necessary. Therefore, estimates of monthly demand are also required. These were obtained from the annual totals by separating the future demands into irrigation and nonirrigation uses. All nonirrigation uses (industrial, municipal, power plant, fish and wildlife flows, transbasin diversions and proposed energy development) were assumed to require equal amounts of water each month. Irrigation demands occur only during the growing season between May and October.

Based on irrigation uses and patterns in Northwestern Colorado, the monthly distribution of the total annual irrigation consumptive use was estimated as shown in Table III-10.

In a given year, of course, this distribution of monthly consumptive water use may vary, primarily as a function of summer

Table III-8. Projected Annual Water Demands from the Yampa and White Rivers in the Year 2000 for Two Potential Levels of Energy Development.[1]

		Baseline Development	Accelerated Development
		Acre-feet	
1. YAMPA RIVER BASIN			
	Coal and Coal Gasification	0	10,500
	Oil Shale	0	0
2. WHITE RIVER BASIN			
	Coal and Coal Gasification	0	0
	Oil Shale	90,300	171,800

[1]Data from: Colorado Department of Natural Resources, 1980.

Table III-9. Projected Increases in Water Demand in the Yampa and White River Basins for the Year 2000 with Nine Levels of Development

Level of development	Yampa River	White River
	Acre-feet	
Low economic development without energy development	25,000	8,000
Medium eceonomic development without energy development	40,000	15,000
High economic development without energy development	47,000	23,000
Low economic development with moderate energy development	25,000	98,300
Medium economic development with moderate energy development	40,000	105,300
High economic development with moderate energy development	47,000	113,300
Low economic development with accelerated energy development	35,500	179,800
Medium economic development with accelerated energy development	50,500	186,800
High economic development with accelerated energy development	57,500	194,800

Table III-10. Monthly Irrigation Consumptive Use Expressed as Fraction of Total Annual Irrigation Consumptive Use

Month	Consumptive Use
	Percent
May	14
June	18
July	28
August	19
September	14
October	8
Growing season total	100

rainfall patterns. But, this variation is so limited that it can virtually be ignored. Based on the above assumptions, monthly water demand can be calculated. Tables III-11 and III-12 give monthly demands in entirety for the six development levels on the White River. However, in this study, water demands and availability at specific locations along the river were also estimated. Specifically, energy development was assumed to occur in the Craig-Hayden region of the Yampa basin and in the Piceance Creek area near Meeker in the White River basin. Therefore, estimates of future water demand from economic growth were also necessary at these points. It was assumed, based on present development patterns and trends, that 75 percent of all future development growth in the Yampa basin would occur above Craig, and 50 percent of all future growth in the White River basin would occur upstream of Meeker. Likewise, these same percentages of the basinwide water demand would occur above these locations.

Table III-11. Additional Monthly Water Demands Projected for Various Levels of Economic and Energy Development in the Yampa River Basin

Development level	Water demands						
	Nov.-April	May	June	July	Aug.	Sept.	Oct.
				Acre-feet			
Low	2,080	2,080	2,080	2,080	2,080	2,080	2,080
Low, with some energy development	3,000	3,000	3,000	3,000	3,000	3,000	3,000
Medium, with some energy development	3,000	3,600	3,700	4,100	3,800	3,500	3,300
Medium, with accelerated energy development	3,900	4,500	4,600	5,000	4,700	4,400	4,200
High, with some energy development	3,100	4,500	4,900	5,900	5,000	4,400	3,800
High, with accelerated energy development	4,000	5,400	5,800	6,800	5,900	5,300	4,700

Table III-12. Additional Monthly Water Demands Projected for Various Levels of Economic and Energy Development in the White River Basin

Development level	Water demands						
	Nov.-April	May	June	July	Aug.	Sept.	Oct.
	Acre-feet						
Low	4,200	700	700	700	700	700	700
Low, with some energy development	49,200	8,200	8,200	8,200	8,200	8,200	8,200
Low, with accelerated energy development	90,000	15,000	15,000	15,000	15,000	15,000	15,000
Medium	7,800	1,300	1,300	1,300	1,300	1,300	1,300
Medium, with some energy development	52,800	8,800	8,800	8,800	8,800	8,800	8,800
Medium, with accelerated energy development	93,600	15,600	15,600	15,600	15,600	15,600	15,600
High	7,980	2,500	2,800	3,570	2,880	2,370	1,890
High, with some energy development	53,400	10,000	10,300	11,100	10,400	9,900	9,500
High, with acclerated energy development	94,200	16,800	17,100	17,900	17,200	16,700	16,300

CHAPTER IV

HYDROLOGICAL ANALYSIS OF WATER SUPPLIES

I. INTRODUCTION

A. Brief Description of the White River Flows

At present, there are 30 official gauging stations in the White River basin, and 11 of these gauging stations have records of more than five years in duration. For this report, only data from the major gauging station near Watson, Utah, has been used. The flows on the White River are heavily concentrated in May and June. For an average water year of 1853 CFS, if we assume 100 percent consumption, only the water rights decreed prior to 1940 can be satisfied. However, in this region, most of the irrigation of hay and pasturelands is carried out by flooding; therefore, substantial amounts of flow returns to the river and additional water rights can be served. A detailed analysis of the amount of return flow and its effect on the satisfaction of water rights is an extremely complex task (see Holt, 1980). Our main concern here is not how or if each individual water right will be satisfied under the variation of water supply; rather, the main aim of this study is to estimate the variability of the total amount of unutilized water for the basin as a whole.

B. Brief Description of the Yampa River Flows

For this report, flow data for the Yampa River was collected at the gauging stations at Maybell and Lilly, Colorado. Currently, there are 198 decreed water rights, totaling 1,258 CFS. Contrary to the situation for the White River, the Yampa River has a sufficient supply of water to satisfy most of these water rights (under normal water years)

before meeting instream flow and national park requirements. Thus, for the Yampa River, the focus of this study is different from the focus of the study for the White River. A main effort for the Yampa River was to use different assumed instream flow, national park and other flow requirements, to determine whether the Yampa River would be able to satisfy the water delivery requirements of the Upper Colorado River Compact of 1948. According to Raymond Herrmann of the National Park Service, several small research projects are presently being conducted to study the environmental requirements of the National Park Service. The National Park Service requirements were still not known in February of 1984.

Since the 1984 Upper Colorado River Basin Compact stated that the flow of the Yampa River below Maybell, Colorado, must not be reduced below 5 million acre-feet in any consecutive 10-year period, the future flows at Maybell were compared with this Upper Colorado River Basin Compact requirement for <u>any</u> 10 consecutive years. In addition, different increments of future water needs (from the National Park Service, instream flow requirements, energy developments, etc.) were used to study the probability of satisfying the requirements of the 1948 Upper Colorado River Basin Compact. Because there is no Interstate Compact to govern the downstream flow requirements of the White River, water supplies for different years were compared with different amounts of assumed water demands.

II. APPROACHES

Groundwater resources in these two river basins are not being used extensively. This study only investigated the surface water.

The major gauging stations in the Yampa River Basin are at Maybell and Lilly, Colorado, and the major gauging station in the White River Basin is near Watson, Utah. Flow records collected by the U.S. Geological Survey are available for Maybell and Lilly from 1922 to 1980, and for Watson from 1924 to 1980. In order to study the availability of flow, a rather long-term flow sequence is needed. It is generally accepted that long-term data can be generated from hydrological time series models (see Salas et al., 1980). Several stochastic models are available for modeling hydrologic time series. These models include autoregressive models, broken line models, models of intermittent processes, disaggregation models, Markov mixture models, ARMA-Markov models and general mixture models. All of these models have advantages and limitations. One practical technique to investigate the applicability of a model to a special time series is through the comparison of respective statistical characteristics between that for the natural record and that for the generated series. Conceptually, only virgin flow records can be generated and not the flow after consumption, because the water quantity used for consumption does not follow any natural laws. A great deal of effort was spent to estimate the consumptive usages of water for the past 50 years, so that virgin flow could be estimated and 1000 years of stream flow data generated.

III. ESTIMATION OF CONSUMPTIVE WATER USAGES AND VIRGIN FLOWS ON THE YAMPA AND WHITE RIVERS

Some work had been done in the past to determine the virgin flow in the White River. However, due to a lack of data, little work had been done in regard to virgin flow in the Yampa River. The purpose of this study was to determine the virgin flow of the Yampa River in order to

generate stream flow data for 1000 years. This provided a long-time series for statistical analysis of possible shortages of water (i.e., run analysis). This same analysis was also done on the White River.

Estimation of virgin flow was based on historical stream flow and historical consumptive uses of water, including irrigation, municipal and industrial uses, changes of storage in reservoirs, evaporation from reservoirs, transmountain diversions and other miscellaneous minor items.

The consumptive usage upstream from Lilly, Maybell, and Watson for all previous years with flow data available were collected (see exact dates of available data above). For each flow station the consumptive use for each month was added to the corresponding flow data for that month to obtain the virgin flow for the particular month. By adjusting the flow data to include water that was consumed, 1000 years of data could be generated for virgin flow for these three gauging stations with the assistance of the appropriate stochastic model.

After virgin flow data was generated, the future consumptive use for each month was estimated and subtracted to obtain the future flow predictions for the three gauging stations.

Since the future water demands, including the consumptive use, are difficult to predict, the nine scenarios discussed in Chapter III were used. It was then possible to compare each of these scenarios with the water supply, as will be described in Chapter V.

IV. CONSUMPTIVE USE OF WATER BY VARIOUS CATEGORIES

All the estimated consumptive uses for water from the Yampa River basin from 1910 to 1980 and for the White River basin from 1922 to 1980 are given in Appendix C. Some description of these are given below.

A. Estimation of Irrigated Acreages

Colorado Agricultural Statistics[1/] published irrigation acreages for various crops (corn, spring and winter wheat, oats, barley, potatoes and some data on alfalfa and other hay) back to 1890. The statistical data were compiled by counties. The Yampa River Basin consists of almost the entire area of Routt County and Moffat County, and the White River Basin consists of Rio Blanco County.

Statistics were not available prior to 1975 for irrigated acreage of alfalfa and other hay. The ratios of irrigated acreage to total acreage for these two items have not changed significantly historically, as can be clearly seen from the statistics in Table 1 (taken from 1975-1980), therefore average ratios were taken for estimating the irrigated acreages for these two items for the rest of the years from 1922 to 1973.

For irrigated pastureland, which constitutes 80 to 90 percent of total irrigated land, no statistics by county were readily available on a year-to-year basis. For the present estimation, total irrigated acreages of only crops and hay were subtracted from the total irrigated farmland acreages which are available in "Water Division No. 6 Annual Report" from 1960 to 1979. Data prior to 1960 are not available because of a fire that occurred at the Water District Office in Steamboat Springs. For the other years prior to 1960, total irrigated farmland acreages were obtained from Census of Agriculture[2/] Vol. 1, "Area

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[1/] Source: Colorado Agricultural Statistics Annual Report, Colorado Crop and Livestock Reporting Service, Colo. Dept. of Agricultural and S.R.S. U.S. Dept. of Agriculture.

[2/] Census of Agriculture, Vol. 1, Area Report, Section 2, County Data, Bureau of the Census, U.S. Dept. of Commerce, G.P.O. Washington, D.C. 1919, 1929, 1949, 1954, 1959, 1964, 1969, 1974, 1979, etc.

Report, Section 2, County Data," which provides data at five-year intervals. Thus, only a few years of data were available. Appendix A gives the estimated irrigated pasture acreages over 22 years, averaging 43,475 acres annually for the Yampa River Basin, and for 20 years, averaging 12,804 acres annually for the White River Basin. Due to a lack of statistical information, these averaged values were used for the remainder of the years. Efforts were made to find some correlation between stream flow and pastureland consumptive use, but no correlation was found after plotting these two variables on the graph.

B. Irrigation Consumptive Use

Table IV-1 below, lists crop consumptive water use data for these two basins. The data for Table IV-1 is extracted from Table 3 in "Irrigation Development Potential in Colorado."[3/] The consumptive use or evapotranspiration needs of an individual crop are stated in terms of acre-feet per year per irrigated acre and are net of the effective precipitation for a normal rainfall year.

Table IV-1. Consumptive Use Irrigation Requirements for the Yampa and White River Basins Under Normal Year Precipitation

Crop	Consumptive Use
	A.F./ac./yr.
Wheat	0.7
Corn	1.1
Oats	0.7
Barley	0.7
Potatoes	1.1
Alfalfa	1.5
Other hay	1.3
Pasture	1.0

[3/] Whittlesey, N. K., Irrigation Development Potential in Colorado, AE3 Environmental Resources Center, C.S.U., Fort Collins, Colorado, May 1977.

With the consumptive use quotas for irrigation, estimates of consumptive use for each crop and total annual consumptive use from irrigation were obtained. Appendix A illustrates this estimation for 1922 to 1980.

C. Monthly Distribution of Irrigation Consumptive Use

Based on irrigation patterns in northwestern Colorado (Federal Energy Administration, 1977), the monthly distribution of the total annual irrigation consumptive use was estimated as shown below in Table IV-2. Irrigation demands occur only between May and October.

Table IV-2. Irrigation Monthly Consumptive Use Expressed as Fraction of Total Annual Irrigation Consumptive Use

Month	Consumptive Use
	Percent
May	14
June	18
July	28
August	19
September	14
October	8
	100

D. Reservoir Evaporation and Storage Changes

The Yampa River basin had no major reservoirs prior to 1940 when Stillwater Reservoir was built. Therefore, for this basin, reservoir evaporation and storage changes were not taken into account even though several small reservoirs existed prior to 1940. After 1940, some major reservoirs were built, the largest of which are listed in Table IV-3.

Reservoir evaporation was estimated for the Yampa River for all years after 1940, by the Colorado Division of Water Resources, Division No. 6 Office at Steamboat Springs. These evaporation estimates are given in Appendix C.

Table IV-3. Major Reservoirs in the Yampa River Basin

Reservoirs	Capacity
	Acre-feet
Elkhead	13,390
Pearl Lake (Lester Creek)	5,660
Steamboat Lake	23,060
Lake Catamount	7,400
Yamcolo	9,000
Stillwater	6,390

The current estimates for reservoir evaporation and storage changes were simpler for the White River. According to "Water and Related Land Resources, White River Basin, in Colorado," from 1924 to 1960 reservoir evaporation and storage changes account for only 1 percent of the total consumptive use of water. This ratio was used when data were not available in certain years prior to 1961.

Due to a lack of data during part of the years from 1945 to 1948, the average figures for the rest of each particular year were used.

E. Municipal and Industrial Use

As mentioned above, municipal and industrial data for 1976 to 1980 were also available in "Division No. 6 Water Budget Program." The table in Appendix C of the Water Division Annual Report provides these data for some years. Since municipal and industrial uses have an upward trend and do not change significantly from year to year, it is reasonable to interpolate estimated values between known values.

For the White River basin, Longenbaugh and Wymore (1971) found that municipal and industrial uses accounted for 4 percent of the total consumptive use before 1960. This percentage was used to estimate values prior to 1961. Based on the same source, 8 and 11 percent were used for the 1960's and 1970's respectively.

It was assumed that annual municipal and industrial use was distributed evenly over the months in each year.

F. Transmountain Diversion

Three data sources were available: (1) Water Division Annual Report contains data from 1961 to 1975 (see Appendix C, p. 28) for the Yampa River basin; (2) "Division No. 6 Water Budget Program" provides data compiled from 1976 to 1980; (3) Table in Appendix C (p. 26) of Water Division No. 6 Annual Report provides certain years prior to 1961. Interpolations were made for the years with missing data.

No transmountain diversions have been made from the White River basin.

G. Miscellaneous Item

Accounting of miscellaneous water in the Yampa River basin was not made until 1976 and on. Some amount of water was then recorded as miscellaneous use in the "Division No. 6 Water Budget Program." As for the White River, a small amount of water was accounted as a miscellaneous item based on 1976-1980 data provided in the "Water Budget Program."

We have used the above approach to get a reasonable estimate of the amount of miscellaneous use of water. The amounts of miscellaneous use are very small and thus should have an insignificant effect on this study.

V. DATA GENERATION

A. Selection of a Stochastic Model for Hydrological Data Generation

Virgin flows were estimated based on the data from 1922 to 1980 for the Yampa River (at Maybell and Lilly) and from 1924 to 1980 for the White River (near Watson) as explained previously. Four stochastic

models were identified to determine the most appropriate model which would preserve the statistical parameters and would also satisfy the test for independence of the residual variable, a skewness test for normality and heteroscedascity test for white noise variance. The four models were AR(0), AR(1), AR(2) and ARMA(1,1), and they are described in "Hydrological Modeling for Time Series" (Jose Salas et al., 1980).

For some months the coefficients of skewness were quite high, as shown in Table IV-4. As a result, none of the four models could satisfy the skewness test for normality without doing a transformation of the series. For the Yampa River, the best computer value of skewness was 1.001 using model AR(2) which is still far from the tabulated value of 0.180. The same case developed with the White River data. Therefore, a natural logarithm transformation of series was done for both the Yampa and the White Rivers, using the following equation:

$$X = LOG\ (Y + C)$$

where

X = transformation series,

LOG = natural logarithm

Y = historical series

C = transformation coefficient.

Table IV-4. Coefficient of Skewness for the Yampa and White River Series

Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
Yampa River											
1.08	1.04	0.73	0.52	2.24	1.55	0.72	0.21	0.17	1.91	0.83	1.89
White River											
1.86	1.47	0.80	0.28	1.20	1.55	2.89	0.79	3.63	2.57	3.12	4.41

Probability levels (Beta) with 0.90 and 0.95 and significance levels with 0.025 and 0.05 were selected in the identification of suitable models.

It can be clearly seen that for both the Yampa and the White the most appropriate stochastic model was the AR(2) model, even though the computed skewness values were not close to the tabulated values.

B. Results of Hydrologic Data Generation

The generation of the 1000-year data was done by generation of five samples of 200 years each. The five samples were listed for every month and were compared to the historical parameters of the corresponding months. The closeness of these values suggested a satisfactory model had been used. Tables IV-5 and IV-6 show the closeness of parameters for the 1000-year generated data compared with those of historical parameters.

The comparison between the generated water supply data and the water demand will be discussed in the next chapter.

able IV-5 --Comparison of statistical parameters of historical series and 1000-year generated series at Maybell and Lilly, Yampa River

Parameters	Series	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
Mean	Historic	36,191	26,407	23,414	21,682	24,248	62,241	22,074	548,717	447,563	130,762	50,003	33,935
	1000-yr.	35,533	26,332	23,353	21,391	23,759	61,078	213,021	524,882	446,242	131,002	49,986	33,538
Standard deviation	Historic	15,165	9,675	7,735	6,664	9,380	33,417	101,208	177,431	172,662	72,095	15,906	12,463
	1000-yr.	13,773	9,570	7,446	6,485	8,583	30,778	100,985	171,223	186,698	78,398	16,427	11,776
Skewness coefficient	Historic	1.08	1.04	0.73	0.52	2.34	1.55	0.72	0.21	0.17	1.91	0.83	1.89
	1000-yr.	1.01	1.41	0.69	0.56	2.04	1.37	0.84	0.19	0.32	2.24	1.11	2.30
Lag 1 auto coeff.	Historic	0.74	0.82	0.84	0.87	0.68	0.49	0.47	0.46	0.60	0.80	0.74	0.63
	1000-yr.	0.72	0.85	0.82	0.86	0.73	0.57	0.48	0.48	0.64	0.82	0.77	0.63
Lag 2 auto coeff.	Historic	0.38	0.64	0.64	0.67	0.61	0.59	0.42	0.32	0.16	0.45	0.63	0.43
	1000-yr.	0.35	0.66	0.65	0.64	0.67	0.60	0.41	0.31	0.16	0.59	0.68	0.47

Table IV-6--Comparison of statistical parameters of historical series and 1000-year generated series near Watson, White River

Parameters	Series	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
Mean	Historic	31,769	24,918	22,530	21,821	22,894	35,292	41,682	104,257	126,706	55,760	38,115	32,516
	1000-yr.	31,706	24,917	22,566	21,584	22,660	34,802	40,814	103,120	151,117	56,496	38,948	33,146
Standard	Historic	8,717	4,973	4,131	4,041	4,808	11,766	21,506	36,194	74,959	31,447	16,337	14,259
deviation	1000-yr.	8,920	4,986	4,108	3,838	4,670	10,797	18,441	35,455	163,135	32,370	19,286	14,908
Skewness	Historic	1.86	1.47	0.80	0.28	1.20	1.55	2.89	0.79	3.63	2.57	3.12	4.41
coefficient	1000-yr.	1.82	2.19	0.74	0.34	1.05	1.66	2.38	0.75	4.74	2.05	2.84	2.60
Lag 1	Historic	0.77	0.86	0.76	0.79	0.51	0.24	0.51	0.64	0.33	0.38	0.81	0.77
auto coeff.	1000-yr.	0.66	0.77	0.69	0.76	0.57	0.25	0.43	0.53	0.50	0.64	0.74	0.42
Lag 2	Historic	0.66	0.66	0.61	0.61	0.52	0.18	0.27	0.43	0.24	0.50	0.28	0.69
auto coeff.	1000-yr.	0.49	0.51	0.52	0.54	0.49	0.23	0.22	0.44	0.18	0.60	0.52	0.50

CHAPTER V

RELATIONSHIPS BETWEEN WATER SUPPLIES AND WATER DEMANDS

I. WATER RIGHTS

A tabulation of adjudicated water rights in the Yampa River basin has been compiled on the CYBER computer from the State Engineer's records. The rights are tabulated by date of appropriation and cubic feet per second claimed. Water rights in the White River basin have been taken from the study by Longenbaugh and Wymore (1971). These data are plotted by year of appropriation in Figure V-1 for the Yampa River basin and in Figure V-2 for the White River basin. In these figures, the mean flow for the irrigation season along with 2-year, 5-year, and 20-year return flow periods are given.

Appendix E lists the Yampa basin water rights by years, including appropriations on the main stem as well as the tributaries. Appendix E-1 contains the direct flow rights and flow requirements in C.F.S. filed on the tributaries, as well as the mainstem of the Yampa, along with the reservoir rights and amounts of water claimed for storage in acre feet (Water Districts 54, 55, 57 and 58).

Mean flows on the Yampa River during the irrigation period appear to be adequate to serve only water rights up to 3,400 C.F.S. of a total of 8,921 C.F.S. appropriated. On the White River, the mean flow is 1,161 C.F.S. to meet appropriated water rights totaling over 6,000 C.F.S. However, return flows allow many water rights above the 1,161 C.F.S. level to be served, depending on location on the stream. The problem that water right holders have is the extreme variation in monthly stream flow on the Yampa and White Rivers as shown in Figures V-3 and V-4. For instance, average monthly flows at Maybell,

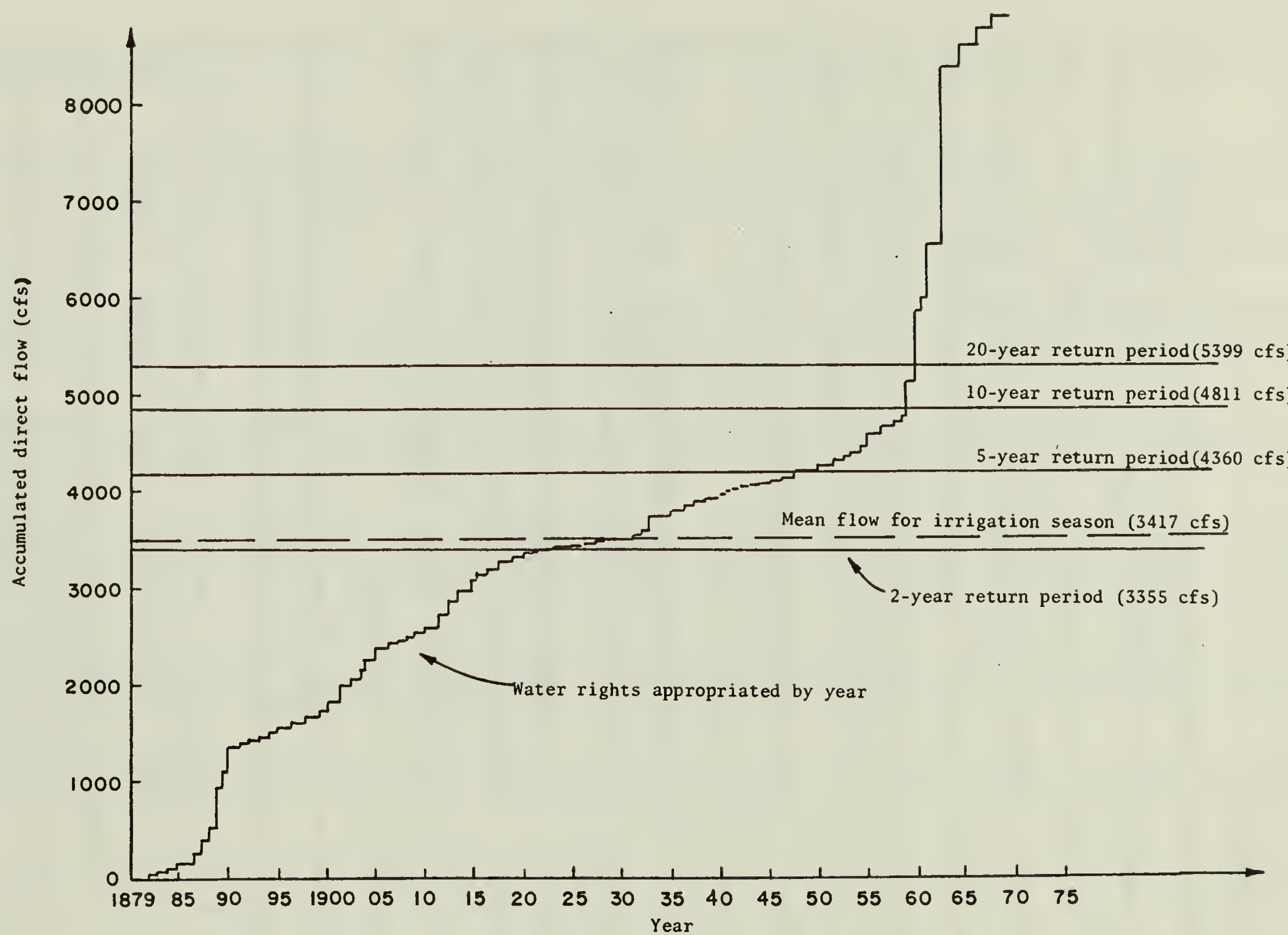

Figure V-1. Absolute and Conditional Direct Flow Water Right Decrees for the Yampa River for the 1879-1980 Period

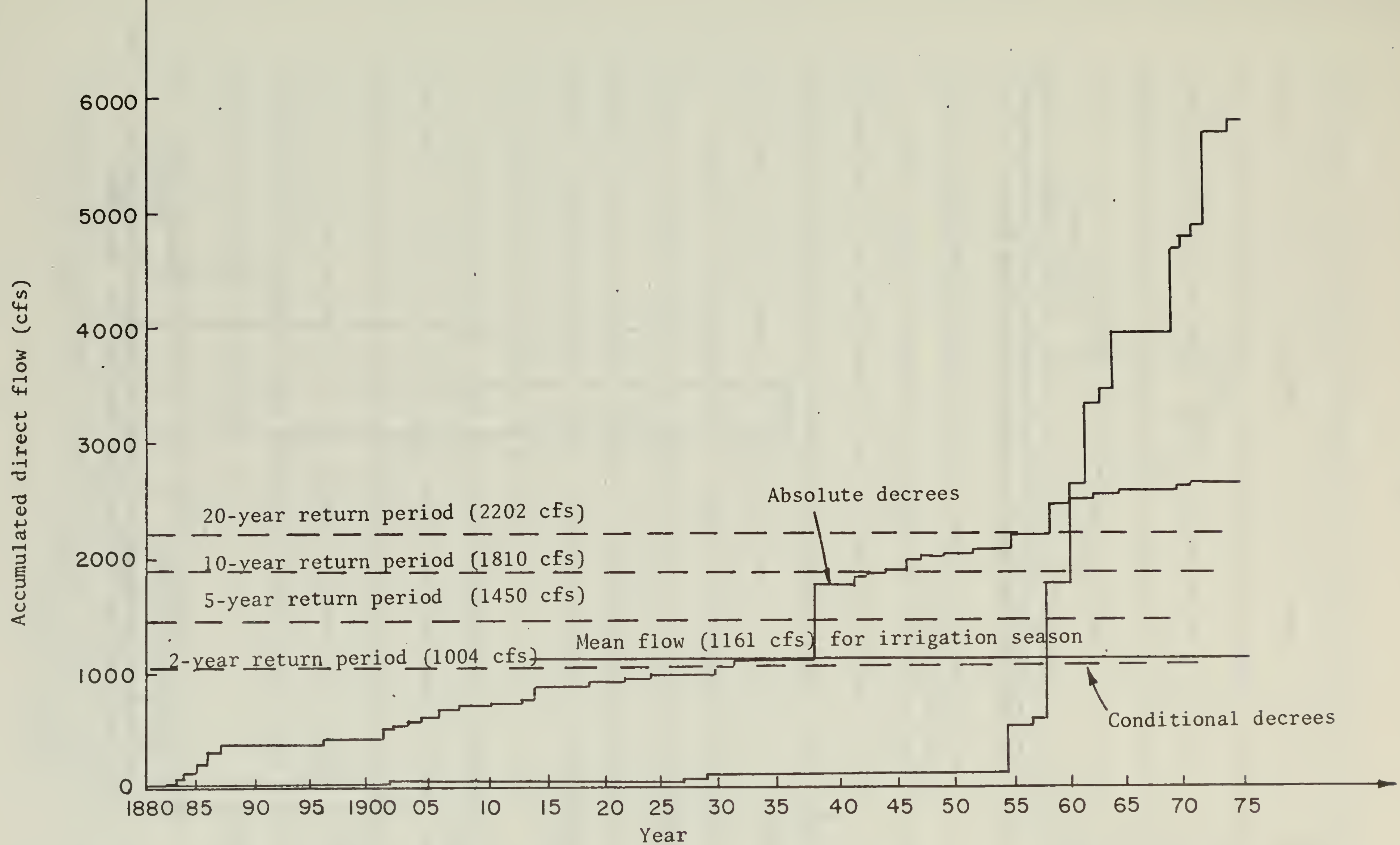

Figure V-2. Absolute and Conditional Direct Flow Water Right Decrees for District 53, White River, for the 1880-1974 Period

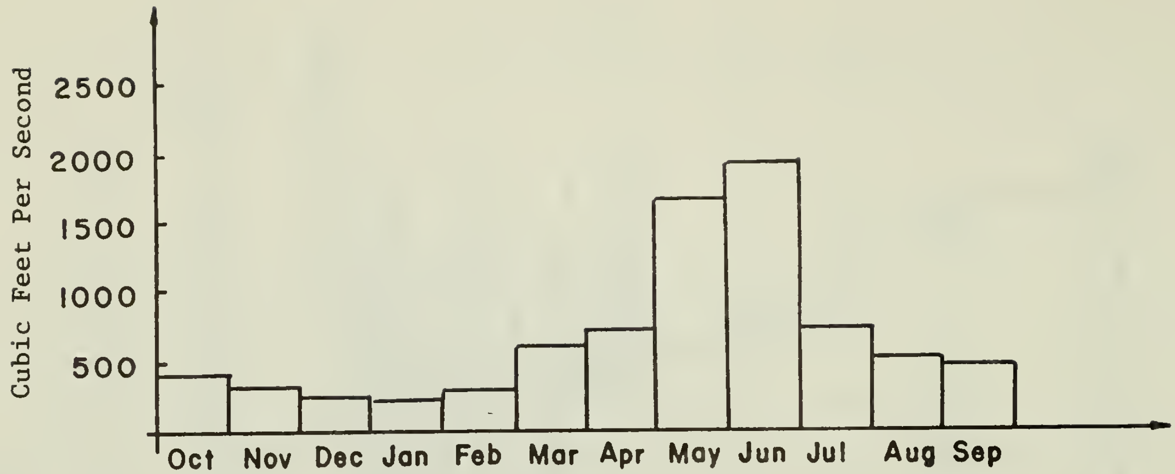

Figure V-3. Average Monthly Stream Flow in C.F.S., White River, near Watson, Utah.

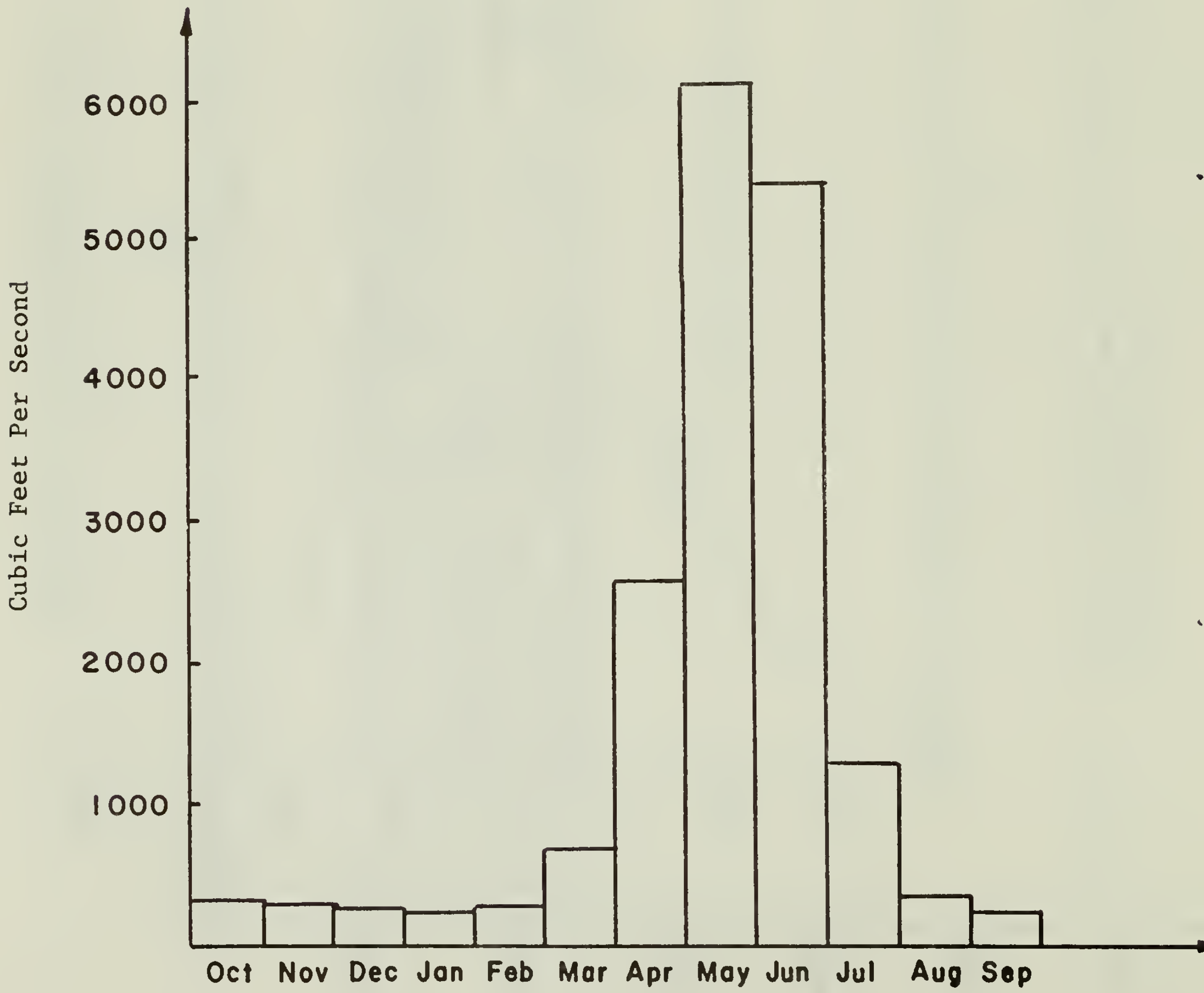

Figure V-4. Average Monthly Stream Flow in C.F.S., Yampa River, Maybell, Colorado.

Colorado, run from about 6,200 C.F.S. in May to 400 C.F.S. in August and about 200 C.F.S. in September. As can be seen, the flow of the Yampa falls off rapidly during the latter part of the irrigation season, leaving many of the water rights without water after June. This rapid decline in stream flow partially accounts for the lack of irrigated crops in the area and for the large acreages of irrigated hay and pasturelands. These lands are irrigated intensively during the short period when water supplies are plentiful and then may not be irrigated again during the growing season.

Most of the active water rights on the Yampa could probably be served during May and June because of the high flows coupled with return flows, but during July, August and September many of the water rights would have little chance of receiving water.

The same general pattern of high early season flows appears to be true on the White River, although diversion records show that appropriations per acre are much higher on the White River than on the Yampa River. Appendix B shows total water diversions, as recorded by the water commissioners on the two rivers.

If the diversions could be made throughout the irrigations season, the water supply on both the Yampa and the White Rivers would be adequate to produce good yields of irrigated crops. The problem is that as the snow melts early in the season, excess water supplies swell the streams, and as the streams decline to low levels late in the season there are short water supplies.

II. COMPARING WATER SUPPLIES AND WATER DEMANDS FOR BOTH BASINS

As shown in previous sections, current water use in both basins is primarily for irrigated agriculture with lesser amounts used for

municipal, industrial and transmountain diversion purposes. Although only about 8 to 19 percent of the annual flow is currently consumed, shortages do occur as a result of high monthly variation in flows. The purpose of this study is to assess water availability and variability for different levels of demands upstream, as well as to satisfy the interstate compact requirement downstream.

In this analysis, one or more consecutive months (for every consecutive 10 years) in which demand exceeds supply is referred to as a "run." For each river basin and for each of the projected demand levels or scenarios, statistics such as the total number of "runs," average and maximum monthly length of "runs," average and maximum volume of deficit of "runs" (depletion), probability of failure to meet demands, return period, average drought severity (ratio of total deficit over total demand), have been tabulated.

One of the main purposes of this part of the analysis is to assess the probability of meeting the interstate compact requirement for the Upper Colorado River. As stated in Chapter II, the Upper Colorado River Compact of 1948,[1/] Article XIII requires that Colorado must not cause the flow of the Yampa River at the gauging station near Maybell, Colorado to be depleted below an aggregate of five million acre-feet for any consecutive 10-year period.

A. Assumptions Used to Compare Supply and Demand

This study considers a combination of nine scenarios according to different levels of energy development and economic growth, as defined in the Upper Colorado River Basin 13(a) Assessment.[2/] Certain

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[1/] Colorado Revised Statutes, 1973, Art. 37-62-101.

[2/] Knudson and Danielson. A Discussion of Legal and Institutional Constraints on Energy-related Water Development in the Yampa River Basin, Colorado, December 1977. State Engineer's Office, Dept. of Natural Resources, State of Colorado, Denver, Colorado.

arbitrarily chosen water demands were also considered. In addition, the following three assumptions were used in this study: 1) all existing water rights are senior to those of energy development; 2) the study has not included any existing significant reservoir storage on the river; and 3) that a 1000-year period, generated and based on the 59-year and 57-year historical records for the Yampa River and the White River respectively, can be used fairly well to assess water availability, and that this corresponds to the economic or planning time frame used for any particular development. The requirements for the instream flows and the Dinosaur National Park are not known at this stage. Thus, these additional water demands, if any, are not considered in this study.

B. Alternative Conditions of Run Analysis

Downstream demands, such as those for Dinosaur National Park, the instream flow, and the Interstate Compact were excluded. Tables V-1, V-2, V-3 and V-4 show the results and statistics of the run analysis when considering nine scenarios of current and anticipated demand from new development. Table V-1, developed for the Yampa River, indicates that there will be deficits or shortages of water with the current demand during 55 periods or "runs," with 71 months having too little water to meet demand. It appears that if storage capacity of 19,414 acre-feet were developed, then these periods of shortages or "runs" would be totally eliminated. In the scenario indicating high level of economic growth with accelerated energy development, in 345 months demand for water could not be met. In this case, storing 37,414 acre-feet of water would eliminate the shortage of water. Additional storage levels needed do not take into consideration the existing storage capacity in this basin. Actually, the additional storage needs cannot

Table V-1. Summary of Run Statistics for the Yampa River Basin (considering upstream demand only)

Level of Development[1/]	Number of Runs	Average Duration (months)	Average Depletion (A.F.)	Average Drought Severity	Maximum Duration (months)	Storage Needed to Satisfy All Demands(A.F.)	Months of Failure	Probability of Failure (percent)	Return Period (year)
Existing	55	1.29	3,900.37	.1175	3	19,413.91	71	0.60	14.0
LWO/LWB	96	1.43	4,413.29	.1273	4	25,653.91	137	1.14	7.3
LWA	129	1.44	4,436.38	.1245	4	28,413.91	186	1.55	5.4
MWO/MWB	155	1.47	4,557.83	.1270	4	30,813.91	228	1.90	4.4
MWA	186	1.51	5,026.13	.1354	4	33,513.91	281	2.30	3.6
HWO/HWB	183	1.52	5,326.63	.1441	4	34,713.91	278	2.30	3.6
HWA	227	1.52	5,537.67	.1448	4	37,413.91	345	2.90	2.9

[1/] LWO, MWO, and HWO refer to: low, medium, and high "without energy development" scenarios.
LWB, MWB, and HWB refer to: low, medium, and high "with baseline energy" scenarios.
LWA, MWA, and HWA refer to: low, medium, and high "with accelerated energy" scenarios.

Table V-2. Summary of Run Statistics for the White River Basin (without river storage)

Level of Development[1/]	Number of Runs	Average Duration (months)	Average Depletion (A.F.)	Average Drought Severity	Maximum Duration (months)	Maximum Depletion (A.F.)
Existing	0	0.00	0.00	0.0000	0	0.00
LWO	0	0.00	0.00	0.0000	0	0.00
LWB	13	1.00	1,250.15	0.0624	1	3,218.45
LWA	260	1.49	2,729.76	0.0713	4	16,397.00
MWO	0	0.00	0.00	0.0000	0	0.00
MWB	17	1.00	1,487.34	0.0720	1	3,818.45
MWA	335	1.50	2,920.36	0.0740	4	18,797.00
HWO	0	0.00	0.00	0.0000	0	0.00
HWB	40	1.00	2,315.43	0.1090	1	6,118.45
HWA	438	1.55	3,975.63	0.0900	4	25,297.00

[1/] LWO, MWO, and HWO refer to: low, medium and high "without energy development" scenarios.
LWB, MWB, and HWB refer to: low, medium and high "with baseline energy" scenarios.
LWA, MWA, and HWA refer to: low, medium and high "with accelerated energy" scenarios.

Table V-3. Summary of Run Statistics for the White River Basin (with river storage to satisfy each individual year)

Level of Development[1/]	Number of Runs	Average Duration (months)	Average Depletion (A.F.)	Average Drought Severity	Maximum Duration (months)	Maximum Depletion (A.F.)
Existing	0	0.00	0.00	0.000	0	0.00
LWO	0	0.00	0.00	0.000	0	0.00
LWB	0	0.00	0.00	0.000	0	0.00
LWA	1	1.00	13,756.36	0.055	1	13,756.36
MWO	0	0.00	0.00	0.000	0	0.00
MWB	0	0.00	0.00	0.000	0	0.00
MWA	1	1.00	16,756.36	0.065	1	16,756.36
HWO	0	0.00	0.00	0.000	0	0.00
HWB	0	0.00	0.00	0.000	0	0.00
HWA	4	1.00	8,770.86	0.033	1	24,456.36

[1/] LWO, MWO, and HWO refer to: low, medium and high "without energy development" scenarios.
LWB, MWB, and HWB refer to: low, medium and high "with baseline energy" scenarios.
LWA, MWA, and HWA refer to: low, medium and high "with accelerated energy" scenarios.

Table V-4. White River (run analysis)

Level of Development[1/]	Number of Negative Runs		Months of Failure		Return Period (years)				Probability of Failure (%)				Storage Needed to Satisfy All Demands (A.F.)
					Irrigation Period		Whole Year		Irrigation Period		Whole Year		
	Without F.S.[2/]	With F.S.	Without F.S.	With F.S.	Without F.S.	With F.S.	Without F.S.	With F.S.	Without F.S.	With F.S.	Without F.S.	With F.S.	
Existing	0	0	0	0					0	0	0	0	0
LWO	0	0	0	0					0	0	0	0	0
LWB	13	0	13.0	0	38.5		76.9		0.22	0	0.11	0	3,218
LWA	260	1	387.4	1	1.29	260.4	2.58	520.8	6.44	0.016	3.22	0.008	16,397
MWO	0	0	0	0	0		0		0	0	0	0	0
MWB	17	0	17.0	0	29.4		58.8		0.284	0	0.142	0	3,818
MWA	335	1	502.5	1	0.99	260.4	1.99	520.8	0.84	0.016	0.42	0.008	18,797
HWO	0	0	0	0	0		0		0	0	0	0	0
HWB	40	0	40	0	12.5		25.0		0.66	0	0.33	0	6,118
HWA	438	4	678.9	4	0.74	63.1	1.47	126.3	1.12	0.066	0.56	0.033	25,297

1/ LWO, MWO, and HWO refer to: low, medium, and high "without energy development" scenarios.
LWB, MWB, and HWB refer to: low, medium, and high "with baseline energy" scenarios.
LWA, MWA, and HWA refer to: low, medium, and high "with accelerated energy" scenarios.

2/ F.S. = further storage.

3/ Compared with condition of no additional storage ("without storage").

be determined from this simple analysis of balancing just the water supply with the water demand. A detailed analysis must be made on the ability to forecast the flow, the operation rules of the storage, the water rights, the water distribution, the downstream seasonal water demands, and other factors, for the determination of the needs for additional storage.

Two conditions were assumed for the White River. With the current condition (without reservoir storage) no deficits appeared on the existing and LWO (low level without energy development) scenarios. However, shortages of water begin to appear on the LWB (low level with baseline energy development) scenario which would require 3,218 acre-feet of storage to eliminate the 13 "runs" or periods of shortage. Furthermore, 25,297 acre-feet of storage would be needed to eliminate the 438 negative "runs" that occur with high economic and accelerated energy development. Again, it is not the purpose of this study to investigate the need for additional storage. More work has to be done to fully investigate the need for storage.

The second condition considered was with reservoir storage to satisfy each year's shortage. In this case, a water deficit appeared for one "run" for LWA (low level with accelerated energy development), one "run" for MWA (medium level with accelerated energy development) and for 4 "runs" for HWA (high level with accelerated energy development).

The statistics in Table V-4 indicate the low probability of shortage of water in a 1000-year period even with not storage of water provided on the White River.

This next series of analyses considered the Upper Colorado River Interstate Compact that applies to the Yampa River, along with upstream

demands. The two conditions considered for the Yampa River basin were with and without additional storage for upstream demand. Obviously, there would be less water flowing downstream if there was a storage reservoir large enough to store water during the wet seasons and allocate water to meet the demand during the dry seasons. In such a case, it would be more difficult to satisfy the five million acre-feet for every 10 consecutive years than in the case where no storage is available to meet upstream demands. However, results of the analysis showed that with all nine scenarios and existing conditions, there were no negative runs for these two conditions. In order to find a level of upstream demand beyond which the negative "runs" begin to occur, four additional development levels were projected, based on the total annual upstream demands. As Table V-5 shows, a "run" or shortage did not occur with additional development until annual upstream demand reached 1,200,000 acre-feet. In other words, when there is no additional storage for upstream demand a deficit will occur once in 99 years in terms of the downstream compact commitment. Table V-6 shows that shortage of water occurred only when additional development level (extra high-3 scenario) reached 800,000 acre-feet for the total upstream demand, when additional storage for upstream demand was available. Nine runs with a total number of forty-two 10-year periods were recorded in this case. This means that water shortage would occur every 2.4 years. The additional storage levels needed for various levels of upstream demand are also listed in the table. Also, if negative "runs" are to be totally eliminated in the extra h-3 scenario, the storage needed to meet the compact will be 13,624,498 acre-feet; or if no storage is provided, then the maximum shortage duration will be fourteen 10-year periods, i.e., 140 years, as shown in Table V-7.

Table V-5. Run Analysis for Yampa River (without additional storage for upstream demand and the Upper Colorado River Compact Requirement for 5,000,000 A.F. in any 10-year Period

Level of Development[1/]	No. of Negative Runs	Average Duration (10 years)	No. of 10 Years of Failure	Average Depletion (A.F.)	Maximum Duration (10 years)	Maximum Depletion (A.F.)	Return Period (10 years)	Probability of Failure (percent)	Total Annual Upstream Demand(A.F.)
Existing	0	0	0	0	0	0	∞	0	140,335
LWO/LWB	0	0	0	0	0	0	∞	0	165,295
LWB	0	0	0	0	0	0	∞	0	176,335
MWO/MWB	0	0	0	0	0	0	∞	0	180,335
MWA	0	0	0	0	0	0	∞	0	191,135
HWO/HWB	0	0	0	0	0	0	∞	0	187,435
HWA	0	0	0	0	0	0	∞	0	198,235
Extra High-1	0	0	0	0	0	0	∞	0	400,000
Extra H-2	0	0	0	0	0	0	∞	0	600,000
Extra H-3	0	0	0	0	0	0	∞	0	800,000
Extra H-4	1	1	1	7,727	1	7,727	99.1	0.1	1,200,000
Extra H-5	7	5.86	41	2,411,156	18	9,140,594	24.0	4.1	1,500,000

[1/] LWO, MWO, and HWO refer to: low, medium, and high "without energy development" scenarios.
LWB, MWB, and HWB refer to: low, medium, and high "with baseline energy" scenarios.
LWA, MWA, and HWA refer to: low, medium, and high "with accelerated energy" scenarios.

Table V-6. Run Analysis for Yampa River (with additional storage for upstream demand) and the Upper Colorado River Compact Requirement for 5,000,000 A.F. in any 10-year Period

Level of Development[1/]	No. of Negative Runs	Average Duration (10 years)	No. of 10 Years of Failure	Average Depletion (A.F.)	Maximum Duration (10 years)	Maximum Depletion (A.F.)	Return Period (10 years)	Probability of Failure (percent)	No Additional Storage for Upstream Demand (A.F.)	Total Annual Upstream Demand (A.F.)	Additional Storage for UpstreamDemand (A.F.)
Existing	0	0	0	0	0	0	∞	0	0	140,335	19,413
LWO/LWB	0	0	0	0	0	0	∞	0	0	165,295	25,654
LWA	0	0	0	0	0	0	∞	0	0	176,335	28,414
MWO/MWB	0	0	0	0	0	0	∞	0	0	180,335	30,814
MWA	0	0	0	0	0	0	∞	0	0	191,135	33,514
HWO/HWB	0	0	0	0	0	0	∞	0	0	187,435	34,713
HWA	0	0	0	0	0	0	∞	0	0	198,235	37,414
Extra High-1[2/]	0	0	0	0	0	0	∞	0	0	400,000	239,179
Extra H-2	0	0	0	0	0	0	∞	0	0	600,000	439,179
Extra H-3	9	4.67	42	3,334,618	14	13,624,498	2.40	4.2	0	800,000	639,179
Extra H-4	51	11.80	614	4,032,198	95	237,500,000	1.61	61.9	0	1,200,000	1,039,179
Extra H-5	991								0	1,500,000	1.3×10^6

[1/] LWO, MWO, and HWO refer to: low, medium, and high "without energy development" scenarios.
LWB, MWB, and HWB refer to: low, medium, and high "with baseline energy" scenarios.
LWA, MWA, and HWA refer to: low, medium, and high "with accelerated energy" scenarios.

[2/] H-1, H-2, etc. refer to: "high" in various degrees.

Table V-7. Additional Storage Needed to Meet Downstream Demand (with additional storage for upstream demand)

Runs	Tenth scenario Storage needed A.F.	(In 10-year periods) Run duration (10-year)
0	13,624,498	0
1	7,094,846	1
2	6,986,661	1
3	767,789	2
4	602,795	3
5	594,729	3
6	249,524	2
7	86,791	9
8	3,931	7
9	0	14

It can be concluded that for the purpose of meeting interstate compact requirements of providing five million acre-feet of water at Maybell in any consecutive ten years, water is abundant in the Yampa River. It is also obvious that the mean annual stream flow of 1,050,000 acre-feet is twice that needed for the annual interstate compact requirement of 500,000 acre-feet. However, if the compact commitment were to be evenly distributed over each year of every 10-year period, it would be much more restrictive for water use on the upper Yampa. An analysis was made in regard to this scheme and is attached to this report as Appendix D, "Supplement to Run Analysis for the Yampa River."

The Upper Colorado River Interstate Compact that affects the Yampa River requires delivery of 5,000,000 acre-feet of water to the Green

River in any 10-year period. This compact provision guarantees to some degree that water will be made available for minimum flow uses during most time periods. To test the effect of the compact requirement, two alternative situations were run in the computer analysis. Alternative one attempts to deliver a uniform 500,000 acre-feet per year from the Yampa River. This alternative tries to meet the 500,000 acre-feet requirement during the 6-month nonirrigation period; the remaining water needed would come equally from the six irrigation months. In this case every year for about 1.5 months there would be insufficient water sometime during August to October, with an average shortage of 14,025 acre-feet. The maximum shortage would be 22,492 acre-feet. As more development takes place on the river, the shortages would grow larger each year during August, September and October.

A second alternative was examined: the entire 6-month nonirrigation season water was used to meet part of the compact requirements, then the excess high flows of May through July were used as much as possible to satisfy the remainder of the compact requirements. In this case, no shortages were observed in meeting compact requirements, but stream flow would be much lower in August, September and October than for the previous alternative because existing water rights would be allowed to use most of the available water.

The only way that existing water rights could receive water and that a minimum flow could be maintained would be to develop reservoir storage to meet all water demands during low flow periods.

C. Frequency Analysis of Generated Flow Series

Frequency analysis was made based on the 1000-year generated series, with the empirical plotting position method (P = m/n+1%), where

m is the order and n is the number of samples. Tables V-8 and V-9 list the results of monthly flows corresponding to 2, 5, 10 and 20 years of return periods along with mean flows for the Yampa and White Rivers.

A study was done in regard to run analysis with fixed probability of return periods. For the Yampa River, it was not possible to analyze the annual shortages of water when considering the five million acre-feet demand for each 10 consecutive years. It was possible to analyze the shortages only when a given part of the compact requirement say 500,000 acre-feet, was distributed annually. Two alternatives for annual deliveries were analyzed and are presented, as discussed above, in Appendix D. The results of these alternatives showed no negative runs for the 2-year return period in Alternative 2. This was more reasonable than Alternative 1 because annual excess water was not wasted in terms of satisfying the 500,000 acre-feet annual demand (see Tables V-10 and V-11). As for the White River, no shortage of water appeared when the return period was two years or longer (see Table V-12).

III. CONCLUDING REMARKS

In this chapter we have compared water supply with water demand under various assumptions of future projected water use. In the majority of cases, the water supplies satisfied the water demands most of the time. However, if future water demands should be very high, water deficiencies will occur. All these analyses are made without consideration of the requirements for Dinosaur National Park and the instream flows, because these requirements are not known at this time.

Table V-8. Yampa River (frequency analysis - streamflow in acre-feet)

Return Period (Years)	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Irrigation season A.F., (cfs)
						A.F.							
2.0	33,299.5	25,077.5	22,090.0	20,795.0	21,865.0	54,281.0	194,324.3	516,440.9	440,095.9	110,804.4	47,384.5	30,941.5	1,198,283 (3,355)
5.0	45,470.0	32,657.4	29,389.0	26,747.6	28,983.2	81,293.4	291,870.3	666,321.2	594,694.9	175,491.0	62,291.2	40,528.4	1,521,506 (4,260)
10.0	53,673.7	38,184.6	33,236.3	29,862.2	34,240.4	101,405,8	348,291.9	743,552.7	682,605.9	220,947.8	71,197.9	47,628.7	1,718,075 (4,811)
20.0	60,818.9	44,199.4	37,674.4	33,238.4	40,918.5	119,833.9	403,509.4	823,875.3	754,671.9	274,883.0	79,778.9	54,971.1	1,928,182 (5,399)
50.0	70,625.9	50,122.0	40,450.4	36,901.0	47,039.3	146,434.8	465,317.4	887,183.0	874,765.6	377,153.7	90,408.7	67,897.6	2,173,518 (6,086)
100.0	80,973.3	55,878.8	44,605.3	38,645.6	53,120.5	165,298.6	504,362.8	965,896.3	947,891.9	419,077.5	102,377.5	74,735.5	2,398,074 (6,715)
Mean	35,533.0	26,332.0	23,353.0	21,391.0	23,759.0	61,078.0	213,021.0	524,882.0	446,242.0	131,002.0	49,986.0	33,538.0	1,221,183 (3,419)

Table V-9. White River (frequency analysis - streamflow in acre-feet)

Return Period (Years)	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Irrigation season A.F.,(cfs)
	A.F.												
2.0	29,659.0	24,070.5	21,988.5	21,373.5	21,894.5	32,822.0	36,396.0	98,536.4	105,596.5	47,355.0	33,125.0	28,778.5	358,414 (1,000)
5.0	37,045.0	27,967.6	25,927.8	24,698.8	26,213.0	41,990.2	50,389.8	131,202.2	210,139.9	75,566.1	48,230.2	40,008.4	518,011 (1,450)
10.0	43,040.8	31,038.9	27,943.4	26,466.4	28,615.0	47,839.1	62,459.7	148,165.2	302,684.6	92,709.7	59,789.8	50,316.2	649,942 (1,819)
20.0	48,922.7	33,741.6	30,214.9	28,548.8	31,817.5	54,475.1	77,848.0	170,674.1	406,319.2	119,246.0	73,251.1	63,405.2	786,608 (2,202)
50.0	57,916.5	37,734.9	33,121.8	30,195.8	35,191.3	64,193.0	98,361.4	189,598.3	628,448.5	166,370.9	100,880.5	85,597.2	1,104,275
100.0	63,698.9	42,903.0	34,780.8	31,271.7	36,682.6	72,373.7	108,483.3	212,881.1	976,296.3	182,000.6	119,359.5	94,810.9	1,436,664
Mean	31,706.0	24,917.0	22,566.0	21,584.0	22,660.0	34,802.0	40,814.0	103,120.0	151,177.0	56,496.0	38,948.0	33,146.0	414,593 (1,161)

Table V-10. Residual Stream Flows (after deducting the demands and interstate compact requirements) for Yampa River (run analysis with fixed probability), Return Period: 2 Years, Alternative No. 1

Level of development 1/	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	No. of negative runs	Average run duration (months)	Average depletion (A.F.)	Maximum depletion (A.F.)
							A.F.									
Existing	-5,558	0	0	0	0	0	0	469,220	388,299	47,597	-6,458	-16,034	2	1.5	14,025	22,492
LWO/LWB	-9,718	0	0	0	0	0	0	465,060	384,139	43,437	-10,618	-20,194	2	1.5	20,265	30,812
LWA	-11,558	0	0	0	0	0	0	463,220	382,299	41,597	-12,458	-22,034	2	1.5	23,025	34,492
MWO/MWB	-11,858	0	0	0	0	0	0	462,620	381,599	40,497	-13,258	-22,534	2	1.5	23,825	35,792
MWA	-13,658	0	0	0	0	0	0	460,820	379,799	38,697	-15,058	-24,334	2	1.5	26,525	39,392
HWO/HWB	-12,458	0	0	0	0	0	0	461,620	380,299	38,597	-14,558	-23,534	2	1.5	25,275	38,092
HWA	-14,258	0	0	0	0	0	0	459,820	378,499	36,797	-16,358	-25,334	2	1.5	27,975	41,692

1/ LWO, MWO, and HWO refer to: low, medium, and high "without energy development scenarios.
LWB, MWB, and HWB refer to: low, medium, and high "with baseline energy" scenarios.
LWA, MWA, and HWA refer to: low, medium, and high "with accelerated energy" scenarios.

Rules: 1. Use nonirrigation period to satisfy 500,000 acre-feet.
2. The remainder evenly distributed among the 6 months of irrigation period (May through October).

Table V-11. Residual Stream Flows for Yampa River (run analysis with fixed probability), Return Period: 2 Years, Alternative No. 2.

Level of development[1/]	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	No. of negative runs	Average run duration (months)	Average depletion (A.F.)	Maximum depletion (A.F.)
	A.F.															
Existing	0	0	0	0	0	0	0	469,220	388,299	19,547	0	0	0	0	0	0
LWO/LWB	0	0	0	0	0	0	0	465,060	384,139	2,907	0	0	0	0	0	0
LWA	0	0	0	0	0	0	0	463,220	377,846	0	0	0	0	0	0	0
MWO/MWB	0	0	0	0	0	0	0	462,620	374,446	0	0	0	0	0	0	0
MWA	0	0	0	0	0	0	0	460,820	365,446	0	0	0	0	0	0	0
HWO/HWB	0	0	0	0	0	0	0	461,620	368,346	0	0	0	0	0	0	0
HWA	0	0	0	0	0	0	0	459,820	359,346	0	0	0	0	0	0	0

[1/] LWO, MWO, and HWO refer to: low, medium, and high "without energy development" scenarios.
LWB, MWB, and HWB refer to: low, medium, and high "with baseline energy" scenarios.
LWA, MWA, and HWA refer to: low, medium, and high "with accelerated energy" scenarios.

Rules:
1. Use nonirrigation period to satisfy 500,000 A.F.
2. The remainder evenly distributed among the 6 months of irrigation period (May through October), then use storage to satisfy the negative depletion to its utmost. OR The remainder is satisfied by the high stream flow from May to July. No storage is needed.

Table V-12. Residual Stream Flows for White River (run analysis with fixed probability), Return Period: 2 Years

Level of development[1/]	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	No. of negative runs	Average run duration (months)	Average depletion (A.F.)	Maximum depletion (A.F.)
	A.F.															
Existing	25,977	23,623	21,541	20,926	21,447	32,374	35,936	92,187	97,675	35,507	24,624	22,480	0	0	0	0
LWO	25,277	22,923	20,841	20,226	20,747	31,674	35,236	91,488	96,975	34,807	23,924	21,780	0	0	0	0
LWB	17,777	15,423	13,341	12,726	13,247	24,174	27,736	83,988	89,474	27,307	16,424	14,280	0	0	0	0
LWA	10,977	8,623	6,546	5,926	6,447	17,374	20,936	77,188	82,675	20,507	9,624	7,480	0	0	0	0
MWO	24,677	22,323	20,241	19,626	20,147	31,074	34,636	90,888	96,375	34,207	23,324	21,180	0	0	0	0
MWB	17,177	14,823	12,741	12,126	12,647	23,574	27,136	83,388	88,875	26,707	15,824	13,680	0	0	0	0
MWA	10,377	8,023	5,941	5,236	5,847	16,774	20,336	76,588	82,075	19,907	9,024	6,880	0	0	0	0
HWO	24,087	22,293	20,211	19,596	20,117	31,044	34,606	89,688	94,875	31,937	21,744	20,110	0	0	0	0
HWB	16,477	14,723	12,641	12,026	12,547	23,474	27,036	82,188	87,375	24,407	14,224	12,580	0	0	0	0
HWA	9,677	7,923	5,841	5,226	5,747	16,674	20,236	75,388	80,575	17,607	17,424	5,780	0	0	0	0

[1/] LWO, MWO, and HWO refer to: low, medium, and high "without energy development" scenarios.
LWB, MWB, and HWB refer to: low, medium, and high "with baseline energy" scenarios.
LWA, MWA, and HWA refer to: low, medium, and high "with accelerated energy" scenarios.

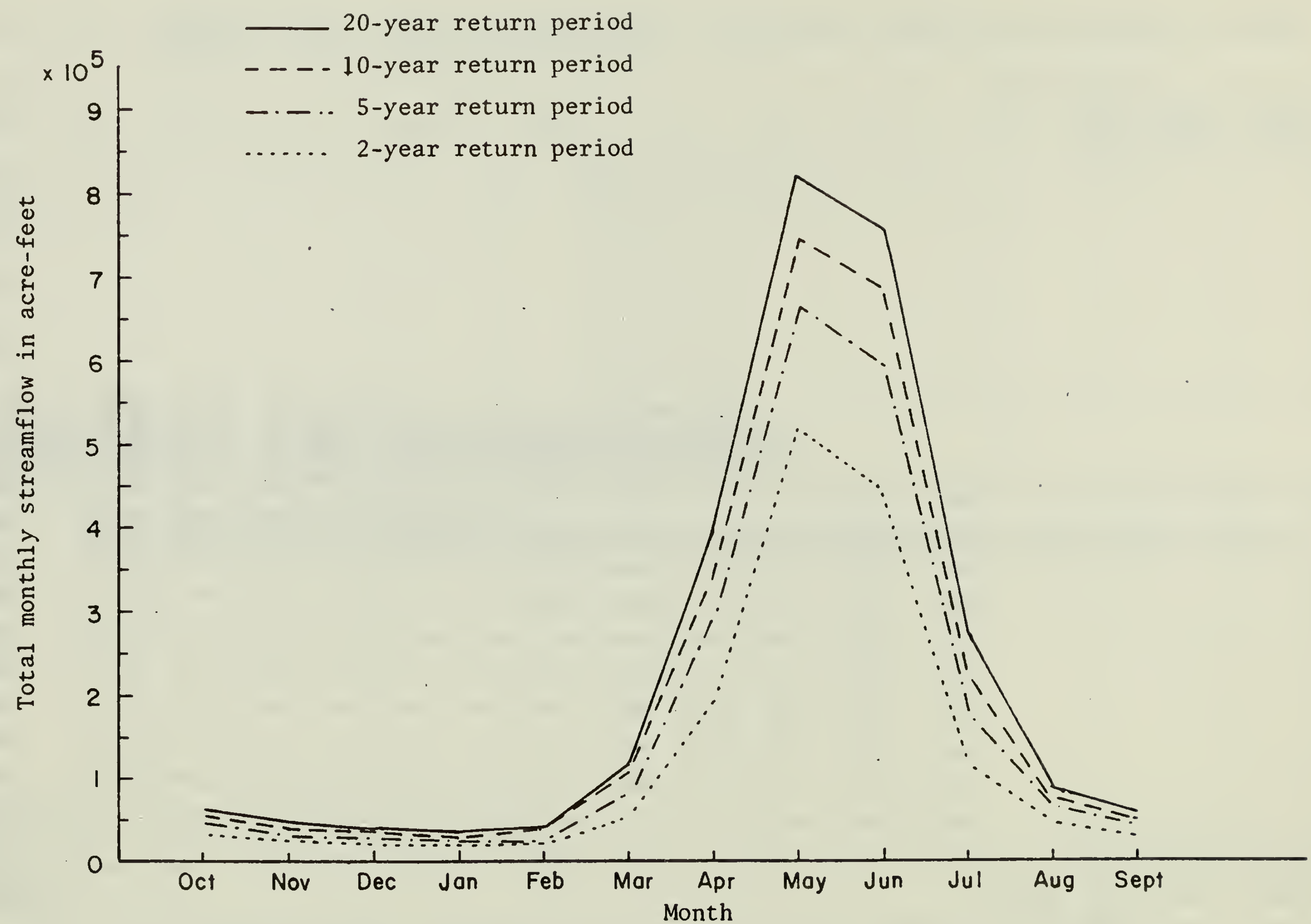

Figure V-5. Frequency of Exceedance for Yampa River at Maybell and Lilly

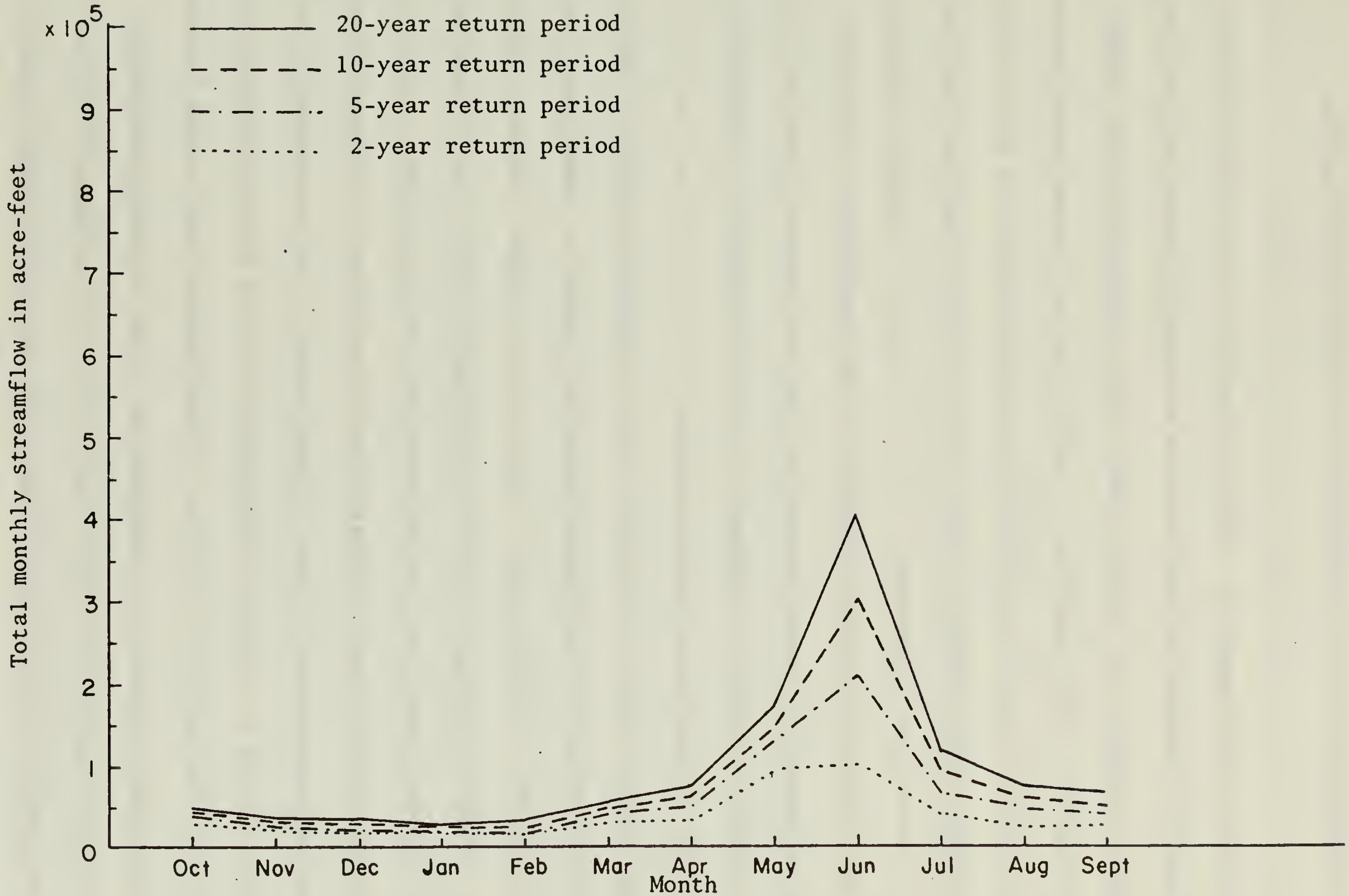

Figure V-6. Frequency of Exceedance for the White River near Watson, Utah.

CHAPTER VI

RESULTS, POTENTIAL IMPLICATIONS AND POSSIBLE STATE ACTIONS

With the development of 1000 year synthetic hydrographs for the Yampa and White rivers, it was possible to examine a wide range of flow conditions for the two rivers. When these hydrographs were matched against current water uses and a variety of anticipated development scenarios it was possible to identify when, how often, how severe, and how lengthy, water shortages were likely to be. Then by examining possible downstream requirements such as interstate compacts, national parks and instream flow requirements, it was possible to estimate the timing and severity of water shortages under various conditions of flow and the amount of reservoir storage that would be needed to redistribute water supply to meet anticipated shortages.

Basically, there is adequate water in both the Yampa and White River basins to meet current requirements for irrigation, municipal, and industrial uses and the water demands of the Upper Colorado River Compact. However, irrigation must remain marginal because of the uneven supply of water during the irrigation season. Too much water is available in May and June and inadequate flows occur during the remainder of the crop growing season. Water rights above those corresponding to daily flow in C.F.S. are able to draw water much of the time because of return flow from upstream diversions. Nonetheless, later in the season many water rights cannot be served because of low stream flows. Excess water flows out of each basin in most years. On the Yampa River over twice the amount of water needed to meet the interstate compact annually flows by the checkpoint gauge at Maybell, Colorado. Given the excess

flow, modest management of the river would allow adequate water supplies for most anticipated development with only occasional shortages. These shortages, as indicated in the previous chapter could be met through construction of reservoirs of varying sizes. The size would depend upon the development potential that the water supply was intended to satisfy.

Since there currently is very weak demand for economic growth, including developments in agriculture, coal mining, power generation, and oil shale in the northwestern river basins, it is unlikely that major water resource development projects will be undertaken at any time in the near future.

This means that the state of Colorado is unlikely to be able to begin to establish claim to its quota of water under the Upper Colorado River Compact. In the meantime, other interests on the river, particularly Arizona and California in the lower basin, are fully utilizing the water of the Colorado River that flows into their jurisdiction. These states are likely to attempt to assert claims on Colorado River water through prior use, and vigorously oppose developments in Colorado (and other upper basin states) that would increase consumptive use in the upper basin. These protests, in addition to water being claimed for instream maintenance for endangered species, reserved water for parks, forests and recreation, could rapidly foreclose whatever opportunity Colorado has to claim and develop any large quantity of water from the Yampa and White river basins.

A scheme announced early in September of 1984, by the Galloway Group Ltd. of Meeker, Colorado, to sell water to San Diego from large reservoirs constructed on the Yampa and White rivers is symptomatic of the pressures that will be put on the rivers and the state of Colorado during the rest of the century.

Consequently, it would seem that the state of Colorado has only a relatively short time span in which to develop and protect its claims to currently unused water in the White and Yampa River Basin.

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APPENDIX A

IRRIGATED AGRICULTURE IN THE YAMPA AND WHITE RIVER BASINS

Irrigated Agriculture in Yampa and White River Basins

During the period 1960 to 1979, irrigated lands in the Yampa River Basin ranged from a high of about 112,000 acres in 1971, to a low of 71,000 acres in 1977. From 1960 to 1979 irrigated crops and haylands ranged from 44,000 to 81,500 acres. The remaining area was irrigated pastureland. Between 1960 and 1979 irrigated lands in the White River Basin ranged from about 39,500 acres to as low as 24,500 acres. Of the irrigated acreages in the White River Basin, between 17,500 and 39,500 acres were crops and haylands. The remainder was irrigated pastureland. Table A-1 shows the irrigated acres in the two basins from 1960 through 1979.

Table A-2 contains estimates of irrigated pasture in the Yampa Basin for selected years, 1929, 1954, and yearly from 1960. Since 1960, irrigated pasture has ranged from 22,000 acres in 1977 (a very dry year) to over 62,000 acres in 1970. Average irrigated pasture acreage 1960 to 1979 was 43,475 acres. In Table A-3 acreages of irrigated pasture in the White River Basin are estimated along with total land irrigated for the period 1960 to 1979. Total irrigated land averaged 33,475 acres during this period and irrigated pasture averaged 12,800 acres. Total irrigated land as compiled by the nine-year census of agriculture for Routt and Moffat counties in the Yampa River Basin and Rio Blanco County in the White River Basin is shown in Table A-4. These figures show a fairly stable irrigated base for a long period of time in each of these basins in Colorado. Tables A-5 through A21 contain irrigated acres of selected crops and estimated consumptive use of water by year from 1922 through 1981. These tables report the acreages of irrigated crops and estimate the consumptive use of irrigation water by years for counties

in the Yampa and White River basins in Colorado. Some of the data, particularly in earlier years, are sketchy; however, these tables give estimates of water consumptively used in the basins for a fairly long period of time.

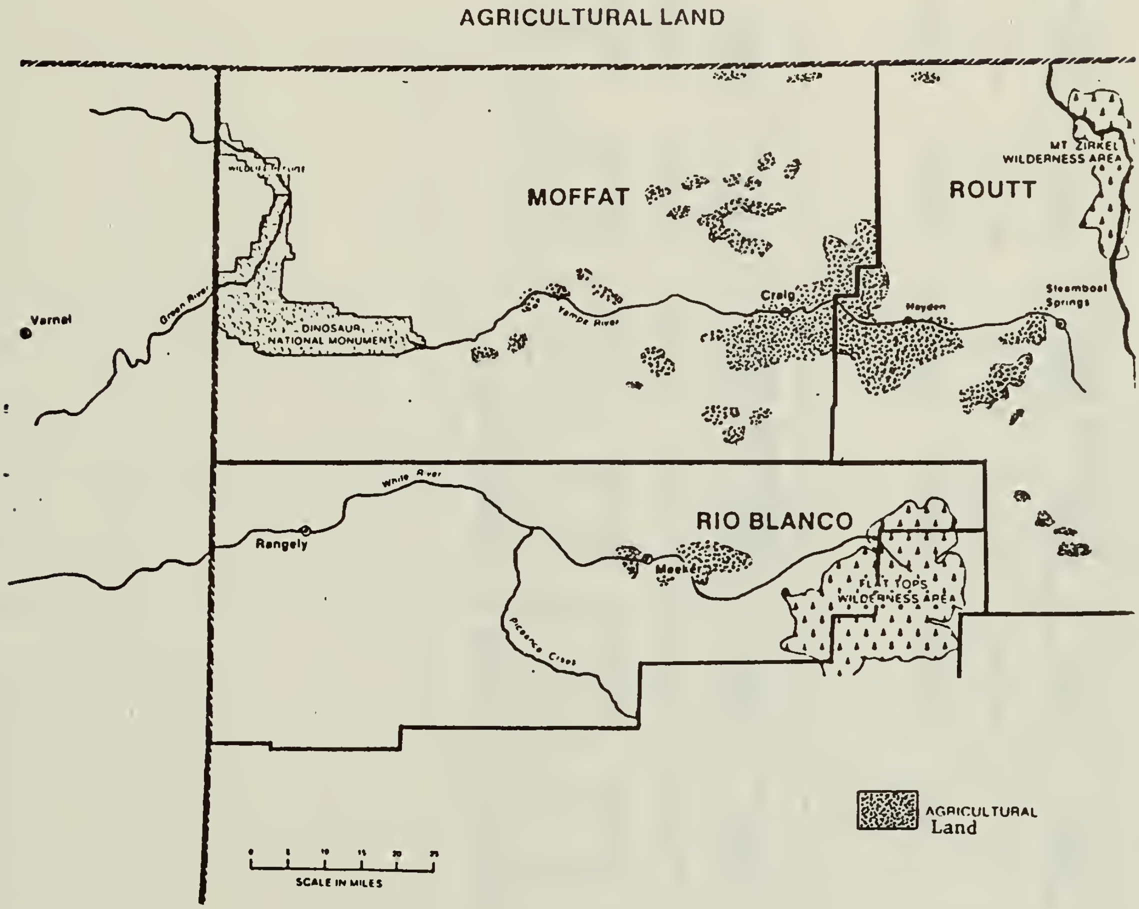

Figure A-1. Agricultural lands in Moffat, Routt and Rio Blanco counties, Colorado. Most agricultural lands are irrigated, with the bulk in irrigated hay and pasture. (After Ferraro and Nazaryk. Cumulative Environmental Impacts of Energy Development in Northwest Colorado.)

Table A-1--Irrigated acres in Yampa and White River basins, Colorado, 1960-1979

River basins	Irrigated acres									
	1979	1978	1977	1976	1975	1974	1973	1972	1971	1970
Yampa	98,315	91,817	71,427	100,070	105,156	110,164	107,162	106,312	111,937	107,016
White	30,090	29,438	24,371	30,505	38,987	36,489	38,370	30,524	37,210	38,180
	Irrigated acres									
	1969	1968	1967	1966	1965	1964	1963	1962	1961	1960
Yampa	97,955	108,918	107,449	105,610	106,173	99,826	100,058	100,055	99,058	104,063
White	32,429	37,440	34,439	33,879	32,054	31,241	30,486	32,543	30,212	34,617

Source: Division of Water Resources, Division 6, Annual Reports.

Table A-2--Yampa River Basin, irrigated pasture acreage

Year	Irrigated pasture acreage
1929	16,747 1/
1954	10,804 2/
1960	43,972
1961	43,799
1962	36,004
1963	37,305
1964	37,076
1965	53,155
1966	55,130
1967	53,508
1968	55,499
1969	43,540
1970	62,861
1971	52,172
1972	49,187
1973	50,542
1974	56,564
1975	50,356
1976	47,970
1977	22,027
1978	36,317
1979	41,915

1/ Total irrigated acreage (Census of Agriculture) minus crop + hay irrigated agricultural land.
2/ Other values obtained from subtracting crop + hay irrigated acreage (Ag. Statistics) from total irrigated acreage (Water Division Annual Report).
Average irrigated pasture acreage for 22 years = 43,475 acres.

Table A-3--White River Basin, irrigated pasture acreage

Year	Total irrigated land	Total irrigated without pasture	Irrigated pasture
	Acres		
1960	34,617	33,772	845
1961	30,212	26,500	3,712
1962	32,543	31,846	697
1963	30,486	29,380	1,106
1964	31,241	29,490	1,751
1965	32,054	25,080	6,974
1966	33,879	20,413	13,466
1967	34,439	17,517	16,922
1968	37,440	18,439	19,001
1969	32,429	18,030	14,399
1970	38,180	18,430	19,750
1971	37,210	27,055	10,155
1972	36,524	20,020	16,504
1973	38,370	20,760	17,610
1974	36,489	24,800	11,689
1975	38,987	22,400	16,587
1976	30,505	21,800	8,705
1977	24,371	20,700	3,671
1978	29,438	19,900	9,538
1979	30,090	23,000	7,090

Irrigated pasture average for 20 years = 12,804 acres.

Table A-4--Irrigated land by counties in Yampa and White River basins

Year	County: Routt	County: Moffat	County: Rio Blanco	Total
	Acres			
1919	50,735	17,439	28,046	68,174
1929	58,839	17,938	30,526	76,777
1949	41,741	18,240	30,405	59.981
1954	43,280	23,500	29,261	66,780
1959	41,405	20,765	29,009	62,170
1964	48,902	23,169	30,147	72,071
1969	57,061	25,642	29,553	83,703
1974	45,593	22,000	25,879	67,593
1978	47,640	23,249	31,360	70,889

Source: Census of Agriculture

Yampa River stream flow vs. pasture consumptive use

Year	Stream flow	Pasture consumptive use
	A.F.	
1919	956,600	10,100
1929	2,022,700	10,787
1949	1,322,580	13,710
1954	522,210	14,045
1959	814,040	8,720
1964	865,090	12,025
1969	1,103,570	37,161
1974	1,417,470	18,720
1978	1,451,120	21,450

Table A-5--Irrigated acreage for selected crops in Moffat, Routt, and Rio Blanco counties, Colorado, 1922-1924

Crop	Moffat County			Routt County			Rio Blanco County		
	1922	1923	1924	1922	1923	1924	1922	1923	1924
	Acres								
Corn	23	36	58	--	--	--	9	4	5
Winter wheat	57	76	98	115	30	7	32	--	--
Spring "	662	498	246	164	30	34	949	841	1093
Oats	42	1090	533	45	128	453	46	914	1113
Barley	60	92	39	170	96	24	164	54	57
Potatoes	31	54	93	80	35	8	21	8	12
Alfalfa (non-irrigated + irrigated)	9941	11616	12742	3622	3596	8098	11426	10035	13242
Other hay (non-irrigated + irrigated)	11070	9542	8340	43980	24055	35018	12710	5599	7752

* * *

Alfalfa, other hay and pasture irrigated acreage for Yampa and White Rivers basins

	Yampa			White		
	1922	1923	1924	1922	1923	1924
Alfalfa (irrigated) - Yampa, 0.55; White, 0.8						
	7,460	8,367	11,462	9,141	8,028	10,594
Other hay (irrigated) - Yampa, 0.88; White, 0.91						
	48,444	29,565	38,155	11,566	5,095	7,054
Pasture (irrigated)						

Table A-6--Irrigation consumptive use of water on selected crops, Yampa and White River basins, Colorado, 1922-1924

Crop	Yampa			White		
	1922	1923	1924	1922	1923	1924
	A.F.					
Corn (1.1)	25	40	64	10	4	6
All wheat (0.7)	629	440	270	687	589	765
Oats (0.7)	61	853	690	32	640	779
Barley (0.7)	161	132	44	115	38	40
Potatoes (1.1)	122	98	111	23	9	13
Alfalfa (1.5)	11,190	12,551	17,193	13,712	12,042	15,891
Other hay (1.3)	62,977	38,435	49,602	15,036	6,624	9,170
Pasture	43,475	43,475	43,475			
Total consumptive use	118,640	96,024	111,449			

Table A-7--Irrigated acreage for selected crops, Moffat, Routt, and Rio Blanco counties, Colorado, 1925-1934

County	1925	1926	1927	1928	1929	1930	1931	1932	1933	1934
					Acres					
A. Corn										
Moffat	2	20	50	50	--	--	10	50	10	30
Routt	--	--	--	50	250	70	--	--	--	--
Rio Blanco	942	1,130	1,100	1,000	--	--	--	--	--	--
B. Winter Wheat										
Moffat	72	60	120	80	50	90	50	30	80	80
Routt	19	200	150	10	230	30	10	20	--	--
Rio Blanco	99	110	110	130	80	30	10	--	70	60
C. Spring wheat										
Moffat	174	460	290	570	180	140	110	100	170	130
Routt	27	70	30	160	570	20	60	50	40	30
Rio Blanco	230	230	--	120	350	550	330	320	550	390
D. Barley										
Moffat	22	140	110	150	250	130	140	90	80	100
Routt	317	160	400	280	70	170	50	250	120	130
Rio Blanco	30	40	--	20	100	40	90	180	150	90
E. Oats										
Moffat	913	420	250	450	370	610	400	390	330	290
Routt	331	370	210	1,280	450	360	230	80	90	80
Rio Blanco	805	800	--	560	670	1,660	1,540	1,910	1,790	1,660
F. Potatoes										
Moffat	90	50	20	10	10	40	90	80	90	85
Routt	187	90	60	50	75	70	50	145	150	205
Rio Blanco	78	70	60	10	10	10	75	110	110	90
G. Rye (10% irrigated - for grain)										
Moffat	(319)	(475)	(352)	(386)	(414)	(499)	(104)	(186)	(124)	(129)
	3,193	4,750	3,520	3,860	4,140	4,990	1,040	1,860	1,240	1,285
Routt)	(9)	(40)	(37)	(35)	(4)	(14)	(15)	(8)	(9)	(10)
	92	400	370	350	35	140	150	80	90	100
Rio Blanco	(53)	(66)	(123)	(100)	(25)	(21)	(7)	(9)	(11)	(13)
	526	660	1,230	1,000	250	210	65	85	110	130

Table A-7 (cont'd.)

County	1925	1926	1927	1928	1929	1930	1931	1932	1933	1934
	- - - - - -	- - - -	- - - -	- - - -	- - - -	Acres	- - - -	- - - -	- - - -	- - - -
H. Rye (10% irrigated - for pasture)										
Moffat	(124)	(71)	(128)	(136)	(154)	(139)	(126)	(118)	(96)	(102)
	1,242	710	1,280	1,360	1,540	1,386	1,260	1,180	960	1,020
Routt	(4)	(15)	(13)	(14)	(1)	(1)	(3)	(2)		
	36	150	130	140	10	9	30	20	--	--
Rio Blanco	(21)	(24)	(45)	(48)	(9)	(8)	(4)	(5)	(4)	(5)
	205	240	450	480	90	81	40	50	40	50
I. Alfalfa (irrigated + non-irrigated)										
Moffat	13,266	13,230	10,880	11,560	12,500	16,140	13,150	13,900	14,470	12,590
Routt	10,629	10,940	8,580	8,590	7,810	7,210	9,870	9,340	9,460	9,250
Rio Blanco	22,097	25,940	24,940	17,430	16,510	17,980	18,790	19,660	21,050	19,140
J. Hay (other)										
Moffat	10,909	9,570	9,710	18,750	13,510	14,480	16,720	16,650	17,720	12,020
Routt	59,845	44,950	42,760	42,020	39,165	47,620	37,410	41,780	43,820	36,840
Rio Blanco		17,250	15,490	17,250	16,360	18,880	19,850	19,770	21,060	15,600
K. Alfalfa (irrigated) - Yampa, 55%; White 50%										
River basin										
Yampa	13,143	13,294	10,703	11,083	11,171	12,843	12,661	12,782	13,162	12,012
White	13,258	15,564	14,964	10,458	9,906	10,788	11,274	11,796	12,630	11,484
L. Hay (other) - irrigated - Yampa, 88%; White, 91%										
Yampa	62,264	47,978	46,174	53,478	46,354	54,648	47,634	51,418	54,155	42,997
White	14,664	15,698	14,096	15,698	14,888	17,181	18,064	17,991	19,165	14,196
M. Pasture										
Yampa										
White										
Total acreage (without pasture)										
Yampa	77,561	63,312	58,667	64,621	60,030	69,221	61,495	65,485	68,477	56,169
White	34,526	38,830	35,318	31,482	29,306	33,855	34,711	36,239	38,675	31,798

Table A-8--Irrigation consumptive water use, selected crops, Yampa and White River basins, 1925-1934

River basin	1925	1926	1927	1928	1929	1930	1931	1932	1933	1934
					A.F.					
A. Corn (1.1)										
Yampa	2	22	55	110	275	77	11	55	11	33
White	1,036	1,243	1,210	1,100	--	--	--	--	--	--
B. All wheat (0.7)										
Yampa	204	504	413	574	721	196	161	140	203	168
White	230	238	77	175	301	406	238	224	434	315
C. Barley (0.7)										
Yampa	237	210	357	301	224	210	133	238	140	161
White	21	28	--	14	70	28	63	126	105	63
D. Oats (0.7)										
Yampa	871	553	322	1,211	574	679	441	327	294	259
White	564	560	--	392	469	1,162	1,078	1,337	1,253	1,162
E. Potatoes (1.1)										
Yampa	305	154	88	66	94	121	154	248	264	319
White	86	77	66	11	11	11	83	121	121	99
F. Alfalfa (1.5)										
Yampa	19,715	19,941	16,055	16,625	16,757	19,265	18,992	19,173	19,743	18,018
White	19,887	23,346	22,446	15,687	14,859	16,182	16,911	17,694	18,945	17,226
G. Hay (other) (1.3)										
Yampa	80,943	62,371	60,026	69,521	60,260	71,042	61,924	66,843	70,402	55,896
White	19,063	20,407	18,325	20,407	19,354	22,335	23,483	23,388	24,915	18,455
H. Pasture										
Yampa	43,475	43,475	43,475	43,475	16,747	43,475	43,475	43,475	43,475	43,475
White	12,804	12,804	12,804	12,804	12,804	12,804	12,804	12,804	12,804	12,804
Total consumptive use										
Yampa	145,752	127,230	120,791	131,883	95,652	135,065	125,291	130,499	134,532	118,329
White	47,912	49,123	45,928	43,120	43,868	44,138	45,204	45,450	46,070	44,178

Table A-9--Irrigated acreage for selected crops, Moffat, Routt, and Rio Blanco counties, Colorado, 1935-1943

County	1935	1936	1937	1938	1939	1940	1941	1942	1943
					Acres				
A. Corn									
Moffat	49	95	750	60	20	20	90	130	90
Routt	--	--	--	--	--	--	--	--	--
Rio Blanco	30	360	60	90	80	30	80	10	10
B. Winter wheat									
Moffat	302	220	150	100	140	80	70	70	260
Routt	406	350	300	100	150	40	70	30	30
Rio Blanco	63	50	50	160	180	80	50	60	40
C. Spring wheat									
Moffat	270	240	300	200	250	70	50	180	70
Routt	94	80	--	--	--	20	20	20	100
Rio Blanco	575	600	450	590	610	390	240	290	290
D. Oats									
Moffat	1,375	830	750	860	850	610	570	610	440
Routt	--	140	150	160	140	320	170	100	100
Rio Blanco	1,200	1,010	1,110	990	1,210	1,580	1,290	1,360	1,380
E. Barley									
Moffat	230	190	150	220	440	370	490	550	260
Routt	37	20	90	50	40	130	150	80	40
Rio Blanco	150	110	90	110	190	190	250	410	820
F. Potatoes									
Moffat	85	220	340	90	70	40	40	70	50
Routt	404	210	360	--	--	170	140	150	40
Rio Blanco	228	100	90	70	80	60	40	70	180
G. Dry Beans									
Moffat	52	--	--	10	10	10	--	--	--
Routt	--	--	--	--	--	--	--	--	--
Rio Blanco	--	--	--	--	--	--	--	--	--
H. Sorghum (grain)									
Moffat	300	250	200	150	--	--	--	--	--
Routt	--	--	--	--	--	--	--	--	--
Rio Blanco	--	--	--	--	--	--	--	--	--

Table A-10--Acreage for alfalfa and other hay, irrigated and non-irrigated, Moffat, Routt, and Rio Blanco counties, Colorado, 1935-1944

County	1935	1936	1937	1938	1939	1940	1941	1942	1943	1944
	Acres									
A. Alfalfa (irrigated and non-irrigated)										
Moffat	14,630	13,710	14,030	15,840	15,120	12,340	13,080	13,750	13,060	13,990
Routt	11,320	11,020	11,560	12,240	11,310	8,330	8,840	8,930	8,760	10,140
Rio Blanco	16,630	17,530	16,250	16,940	16,290	12,340	11,193	11,530	11,590	11,870
B. Other hay (all tame hay, rye, and wild hay, irrigated and non-irrigated)										
Moffat	13,780	13,160	11,640	12,780	14,010	11,660	12,690	10,700	11,780	14,080
Routt	31,170	33,480	32,900	44,430	43,810	45,770	43,700	44,070	43,520	51,600
Rio Blanco	12,240	11,840	12,520	20,090	20,140	17,810	18,560	17,000	18,910	23,070
C. Alfalfa (irrigated) - Yampa, 55%; White, 50%										
Moffat	8,047	7,541	7,717	8,712	8,316	6,787	7,194	7,563	7,183	7,695
Routt	6,226	6,061	6,358	6,732	6,221	4,582	4,862	4,912	4,818	5,577
Rio Blanco	8,315	8,765	8,125	8,470	8,145	6,170	5,597	5,765	5,795	5,935
D. Other hay (irrigated) - Yampa, 88%; White, 91%										
Moffat	12,126	11,581	10,243	11,246	12,329	10,261	11,167	9,416	10,366	12,390
Routt	27,430	29,462	28,952	39,098	38,553	40,278	38,456	38,782	38,298	45,408
Rio Blanco	11,138	10,774	11,393	18,282	18,327	16,207	16,890	15,470	17,208	24,994

Notes: "Over 90 percent of Colorado alfalfa acreage is grown under irrigation. A large percentage of the wild hay is irrigated." (1939 -

Table A-11--Irrigation consumptive water use, selected crops, Yampa and White River basins, 1935-1943

River basin	1935	1936	1937	1938	1939	1940	1941	1942	1943
					A.F.				
A. All wheat (0.7 AF/A)									
Yampa	750	623	525	280	378	133	147	210	322
White	447	455	350	525	553	329	203	245	231
B. Corn (1.1 AF/A)									
Yampa	54	105	83	66	22	22	99	143	99
White	33	396	66	99	88	33	88	11	11
C. Barley (0.7 AF-A)									
Yampa	180	147	168	189	336	350	448	441	210
White	105	77	63	77	133	133	175	287	574
D. Oats (0.7 AF/A)									
Yampa	963	679	630	714	693	651	518	497	378
White	840	707	777	693	847	1,106	903	952	966
E. Potatoes (1.1 AF/A)									
Yampa	538	473	770	99	77	231	198	242	99
White	251	110	99	77	88	66	44	77	154
F. Dry beans (0.9 AF/A)									
Yampa	57	--	--	11	11	11	--	--	--
White	--	--	--	--	--	--	--	--	--
G. Alfalfa (1.5 AF/A)									
Yampa	21,410	20,403	21,113	23,176	21,806	17,054	18,084	18,713	18,002
White	12,473	13,148	12,188	12,705	12,218	9,255	8,396	8,648	8,693
H. Other hay (1.3 AF/A)									
Yampa	51,423	53,356	50,954	65,447	66,147	65,701	64,510	62,657	63,263
White	14,479	14,006	14,811	23,767	23,825	21,069	21,957	20,111	22,370
Total consumptive use (without pasture)									
Yampa	75,375	75,786	74,243	89,972	89,470	84,153	84,004	82,903	82,373
White									

Table A-11 (cont'd.)

River basin	1935	1936	1937	1938	1939	1940	1941	1942	1943
					A.F.				
I. Pasture and others (1.0)									
Yampa	43,475	43,475	43,475	43,475	43,475	43,475	43,475	43,475	43,475
White	12,804	12,804	12,804	12,804	12,804	10,000	10,000	10,000	10,000
Total consumptive use (with pasture)									
Yampa	118,850	119,261	117,718	133,447	132,945	127,628	127,479	126,378	125,848
White	41,432	41,703	41,058	50,747	47,752	41,991	41,766	40,331	42,999

Table A-12--Irrigated acreage for selected crops, Moffat, Routt, and Rio Blanco counties, Colorado, 1948-1955

County	1948	1949	1950	1951	1952	1953	1954	1955
				Acres				
A. Corn								
Moffat	50	80	60	60	60	60	60	80
Routt	--	--	--	--	--	--	--	--
Rio Blanco	30	20	10	10	50	50	50	50
B. Winter wheat								
Moffat	100	450	150	140	220	110	110	120
Routt	--	20	10	30	30	100	100	100
Rio Blanco	300	70	110	100	160	100	100	90
C. Spring wheat								
Moffat	300	240	140	80	100	720	400	280
Routt	130	100	40	80	30	500	230	210
Rio Blanco	200	190	100	60	100	250	200	160
D. Oats								
Moffat	680	700	470	490	570	450	390	380
Routt	120	250	350	300	300	410	190	180
Rio Blanco	900	1,550	2,260	640	1,050	860	650	670
E. Barley								
Moffat	500	500	270	100	170	280	120	200
Routt	200	70	220	130	80	80	160	120
Rio Blanco	400	400	300	190	250	300	540	380
F. Potatoes								
Moffat	100	30	20	30	40	40	10	10
Routt	120	300	90	120	90	50	80	50
Rio Blanco	70	60	30	20	20	30	30	30
G. Alfalfa (Irrigated + non-irrigated)								
Moffat	12,000	8,740	9,460	8,020	10,160	13,040	10,750	10,810
Routt	9,000	6,400	6,050	6,330	7,120	9,980	7,500	8,300
Rio Blanco	10,000	7,900	7,600	7,410	9,080	9,100	9,380	9,870

Table A-12 (cont'd.)

County	1948	1949	1950	1951	1952	1953	1954	1955
	Acres							
H. Other hay (irrigated + non-irrigated)								
Moffat	12,800	11,330	12,150	9,730	11,860	12,640	12,730	12,310
Routt	46,000	43,930	26,050	25,270	34,290	39,740	36,890	39,180
Rio Blanco	18,700	21,270	18,840	17,220	17,560	17,730	17,300	15,990
				* * *				
River basin								
Alfalfa (irrigated) - Yampa, 55%; White, 80%								
Yampa	11,550	8,327	8,531	7,893	9,504	12,661	10,450	10,511
White	8,000	6,320	6,080	5,928	7,264	7,280	7,504	7,896
Other hay (irrigated) - Yampa, 88%; White, 80%								
Yampa	51,744	48,629	33,616	30,800	40,612	46,094	43,666	45,311
White	14,960	17,016	15,072	13,776	14,048	14,184	13,840	12,792
Total irrigated acreage (without pasture)								
Yampa	65,594	59,696	43,967	40,213	51,806	61,515	55,976	57,552
White	26,917	27,966	26,034	22,618	24,874	25,004	24,817	23,827
Pasture								
Yampa	43,475	43,475	43,475	43,475	43,475	43,475	10,804	43,475
White								

Table A-13--Irrigation water consumptive use, selected crops, Yampa and White River basins, 1948-1955

River basin	1948	1949	1950	1951	1952	1953	1954	1955
				A.F.				
A. Corn (0.7)								
Yampa	55	88	66	66	66	66	66	88
White	33	22	11	11	55	55	55	55
B. All wheat (0.7)								
Yampa	371	567	238	203	266	1,001	588	497
White	350	182	154	112	182	245	210	175
C. Oats (0.7)								
Yampa	630	665	574	553	609	602	406	392
White	630	1,080	1,582	448	735	602	455	469
D. Barley (0.7)								
Yampa	490	399	343	161	175	224	196	224
White	280	280	210	133	175	210	378	266
E. Potatoes (1.1)								
Yampa	242	363	121	165	143	99	99	66
White	77	66	33	22	22	33	33	33
F. Alfalfa (1.5)								
Yampa	17,325	12,491	12,797	11,840	14,256	18,992	15,675	15,767
White	12,000	9,480	9,120	8,892	10,896	10,920	11,256	11,844
G. Other hay (1.3)								
Yampa	67,267	63,218	43,701	40,040	52,796	59,922	56,766	58,904
White	19,448	22,121	19,594	17,909	18,262	18,439	17,992	16,629
H. Pasture (1.0)								
Yampa	43,475	43,475	43,475	43,475	43,475	43,475	10,804	43,475
White	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000
Total consumptive use								
Yampa	129,855	121,266	101,315	96,503	111,786	124,381	84,600	119,413
White	42,818	42,231	40,704	37,527	40,327	40,504	40,379	39,461

Table A-14--Irrigated acreage for selected crops, Moffat, Routt, and Rio Blanco counties, Colorado, 1956-1962

County	1956	1957	1958	1959	1960	1961	1962
	Acres						
A. Corn							
Moffat	60	40	30	--	--	--	--
Routt	--	--	--	--	--	--	--
Rio Blanco	40	20	10	360	--	--	--
B. Winter wheat							
Moffat	150	180	130	600	700	530	460
Routt	90	80	60	80	70	40	60
Rio Blanco	140	90	70	100	100	90	90
C. Spring wheat							
Moffat	140	110	300	100	300	280	150
Routt	260	180	200	100	150	140	160
Rio Blanco	100	120	100	60	60	70	60
D. Oats							
Moffat	370	360	130	200	110	160	80
Routt	340	320	400	270	170	210	90
Rio Blanco	940	1,190	600	400	350	260	200
E. Barley							
Moffat	350	160	40	110	110	120	210
Routt	220	100	50	20	30	30	50
Rio Blanco	320	380	130	220	190	230	240
F. Potatoes							
Moffat	10	20	60	50	40	40	40
Routt	20	40	60	60	30	40	40
Rio Blanco	30	20	20	--	--	--	--
G. Alfalfa (irrigated + non-irrigated)							
Moffat	10,410	11,650	13,280	12,200	11,800	11,800	11,800
Routt	9,190	9,640	12,240	11,200	12,300	12,500	13,100
Rio Blanco	9,110	9,920	12,710	10,900	12,800	14,840	14,500

Table A-14 (cont'd.)

County	1956	1957	1958	1959	1960	1961	1962
	- - - - - -	- - - - - -	- - - - - -	Acres	- - - - - -	- - - - - -	- - - - - -
H. Other hay (irrigated + non-irrigated)							
Moffat	11,150	12,230	8,600	10,800	14,050	10,400	17,500
Routt	40,820	41,820	44,900	35,600	37,230	35,400	38,200
Rio Blanco	16,160	17,020	14,010	14,200	25,090	15,360	21,600
				* * *			
River basin							
Alfalfa (irrigated) - Yampa, 55%; White, 60%							
Yampa	10,780	11,710	14,036	12,870	13,255	13,365	13,695
White	5,466	5,952	7,626	6,540	7,680	8,904	8,700
Other hay (irrigated) - Yampa, 88%; White, 80%							
Yampa	45,734	47,564	47,080	40,832	45,126	40,304	49,016
White	12,928	13,616	11,208	11,360	20,072	12,288	17,280
Total irrigated acreage (without pasture)							
Yampa	58,524	60,864	62,576	55,292	60,091	55,259	64,051
White	23,564	25,244	23,847	22,782	33,772	26,500	31,846
Pasture							
Yampa	43,475	43,475	43,475	43,475	43,972	43,799	36,004
White	10,000	10,000	10,000	10,000	10,000	10,000	10,000

Table A-15--Irrigation water consumptive use, selected crops, Yampa and White River basins, 1956-1962

River basin	1956	1957	1958	1959	1960	1961	1962
				A.F.			
A. All wheat (0.7 AF/A)							
Yampa	448	385	483	616	854	693	581
White	168	147	119	112	112	112	105
B. Corn (1.1 AF/A)							
Yampa	66	44	33	--	--	--	--
White	44	22	11	396	--	--	--
C. Oats (0.7 AF/A)							
Yampa	497	476	399	329	196	259	119
White	658	833	420	280	245	182	140
D. Barley (0.7 AF/A)							
Yampa	399	182	63	91	98	105	182
White	224	266	91	154	133	161	168
E. Potatoes (1.1 AF/A)							
Yampa	33	66	132	121	77	88	88
White	33	22	22	--	--	--	--
F. Alfalfa (1.5 AF/A)							
Yampa	16,170	17,565	21,054	19,305	19,883	20,048	20,543
White	8,199	8,928	11,439	9,810	11,520	13,356	13,050
G. Other hay (1.3 AF/A)							
Yampa	59,454	61,833	61,204	53,082	58,664	52,395	63,721
White	16,806	17,701	14,570	14,768	26,094	15,974	21,464
H. Pasture (1.0 AF/A)							
Yampa	43,475	43,475	43,475	43,475	43,972	43,799	36,004
White	10,000	10,000	10,000	10,000	10,000	10,000	10,000
Total consumptive use							
Yampa	120,542	124,026	126,843	117,415	123,744	117,387	121,238
White	36,132	37,919	36,672	35,641	48,104	39,785	45,927

Table A-16--Irrigated acreage for selected crops, Moffat, Routt, and Rio Blanco counties, Colorado, 1963-1968

County	1963	1964	1965	1966	1967	1968
	Acres					
A. Winter wheat						
Moffat	150	30	130	550	450	200
Routt	40	10	--	--	300	300
Rio Blanco	50	20	90	100	210	730
B. Corn						
Moffat	--	--	--	--	--	--
Routt	--	--	--	--	--	--
Rio Blanco	--	--	--	--	--	--
C. Barley						
Moffat	400	300	260	240	120	130
Routt	50	--	--	--	340	260
Rio Blanco	250	280	360	460	310	410
D. Oats						
Moffat	120	70	300	140	200	130
Routt	30	20	200	--	530	390
Rio Blanco	300	300	330	330	370	340
E. Alfalfa (irrigated + non-irrigated)						
Moffat	13,500	14,500	12,000	9,600	9,600	10,400
Routt	13,200	11,500	12,000	9,800	10,500	10,500
Rio Blanco	14,300	14,500	7,500	7,000	8,600	6,000
F. Other hay (irrigated + non-irrigated)						
Moffat	15,000	14,000	12,770	7,800	8,100	7,800
Routt	38,600	40,500	31,000	36,200	38,100	38,080
Rio Blanco	19,000	19,000	20,000	15,300	10,700	13,350
G. Spring wheat						
Moffat	110	60	410	160	230	100
Routt	--	--	--	--	60	40
Rio Blanco	50	20	100	--	10	10
			* * *			
River basin						
H. Alfalfa (irrigated) - Yampa, 55%; White, 60%						
Yampa	14,685	14,300	13,200	10,670	11,055	11,495
White	8,580	8,700	4,500	4,200	5,160	3,600
I. Other hay (irrigated) - Yampa - 88%; White - 80%						
Yampa	47,168	47,960	38,518	38,720	40,656	40,374
White	15,200	15,200	16,000	12,240	8,560	10,680
Total irrigated acreage (without pasture)						
Yampa	62,753	62,750	53,018	50,480	53,941	53,419
White	29,380	39,490	25,080	20,413	17,517	18,439
J. Pasture						
Yampa	37,305	37,076	53,155	55,130	53,508	55,499
White						

Table A-17--Irrigation water consumptive use, selected crops, Yampa and White River basins, 1963-1968

River basin	1963	1964	1965	1966	1967	1968
			A.F.			
A. All wheat (0.7)						
Yampa	210	70	378	497	728	448
White	70	28	133	70	154	518
B. Barley (0.7)						
Yampa	315	210	182	168	322	273
White	175	196	252	322	217	287
C. Oats (0.7)						
Yampa	105	64	224	98	511	364
White	210	210	231	231	259	238
D. Alfalfa (1.5)						
Yampa	22,028	21,450	19,800	16,005	16,583	17,243
White	12,870	13,050	6,750	6,300	7,740	5,400
E. Other hay (1.3)						
Yampa	61,318	62,348	50,073	50,336	52,853	52,486
White	19,760	19,760	20,800	15,912	11,128	13,884
F. Pasture (1.0)						
Yampa	37,305	37,076	53,155	55,130	53,508	55,499
White	10,000	10,000	6,974	13,466	16,922	19,001
Total consumptive use						
Yampa	121,281	121,218	123,812	122,234	124,505	126,313
White	43,085	43,244	35,140	36,301	36,420	39,328

Table A-18--Irrigated acreage for selected crops, Moffat, Routt, and Rio Blanco counties, Colorado, 1969-1974

County	1969	1970	1971	1972	1973	1974
A. Winter wheat						
Moffat	150	1,100	700	500	500	500
Routt	--	50	400	300	200	200
Rio Blanco	950	200	120	100	300	100
B. Corn (grain)						
Moffat	--	--	--	--	--	--
Routt	10	--	--	--	--	--
Rio Blanco	50	--	--	--	--	--
C. Barley						
Moffat	150	100	100	50	400	300
Routt	100	150	100	50	300	200
Rio Blanco	600	500	600	450	200	500
D. Oats						
Moffat	230	150	100	100	500	--
Routt	140	100	100	100	200	400
Rio Blanco	280	300	300	200	100	300
E. Spring wheat						
Moffat	120	100	100	100	300	900
Routt	--	--	140	100	100	--
Rio Blanco	30	--	--	100	--	--
F. Alfalfa (harvested)						
Moffat	11,300	10,500	19,000	13,000	13,500	8,300
Routt	10,000	9,800	14,500	12,500	14,500	7,100
Rio Blanco	6,500	7,000	11,500	6,900	7,000	4,700
G. Other hay (harvested; includes other tame hay, millet, sudan, small grains, clover, timothy, and misc.)						
Moffat	7,500	6,000	12,000	11,500	12,000	7,900
Routt	40,000	29,500	33,000	36,000	32,000	27,500
Rio Blanco	12,000	13,000	18,500	15,000	16,000	14,500
Alfalfa (irrigated) - Yampa, 55%; White, 80%						
Moffat	6,215	5,775	10,450	7,150	7,425	8,300
Routt	5,500	5,390	7,975	6,875	7,975	7,100
Rio Blanco	5,200	5,600	9,200	5,520	5,600	4,700
Other hay (irrigated) - Yampa, 88%; White, 91%						
Moffat	6,600	5,280	10,560	10,120	10,560	7,900
Routt	35,200	25,960	29,040	31,680	28,160	27,500
Rio Blanco	10,920	11,830	16,835	13,650	14,560	14,500
			***			
Total acreage of irrigation (without pasture)						
Yampa	54,415	44,155	59,765	57,125	56,620	53,600
White	18,030	18,430	27,055	20,020	20,760	24,800
Pasture						
Yampa	43,540	62,861	52,172	49,187	50,542	56,564
White	14,399	19,750	10,155	16,504	17,610	11,689

Table A-19--Irrigation water consumptive use, selected crops, Yampa and White River basins, 1969-1974

River basin	1969	1970	1971	1972	1973	1974
			A.F.			
A. All wheat (0.7)						
Yampa	189	1,190	938	700	770	1,120
White	686	140	84	140	210	70
B. Corn (1.1)						
Yampa	11	--	--	--	--	--
White	55	--	--	--	--	--
C. Barley (0.7)						
Yampa	175	175	140	70	490	350
White	420	350	420	315	140	350
D. Oats (0.7)						
Yampa	259	175	140	140	490	280
White	196	210	210	140	70	210
E. Alfalfa (1.5)						
Yampa	17,573	16,748	27,638	21,038	23,100	23,100
White	7,800	8,400	13,800	8,280	8,400	7,050
F. Other hay (1.3)						
Yampa	54,340	40,612	51,480	54,340	50,336	46,020
White	14,196	15,379	21,886	17,745	18,928	18,850
G. Pasture (1.0)						
Yampa	43,540	62,861	52,172	49,187	50,542	56,564
White	14,399	19,750	10,155	16,504	17,610	11,689
Total consumptive use						
Yampa	116,087	121,761	132,508	125,477	125,728	127,434
White	37,752	44,229	46,555	43,124	45,358	38,219

Table A-20--Irrigated acreage for selected crops, Moffat, Routt, and Rio Blanco counties, Colorado, 1975-1981

County	1975	1976	1977	1978	1979	1980	1981
				Acres			
A. Winter wheat							
Moffat	500	1,200	1,100	500	500	500	500
Routt	400	500	500	200	200	200	200
Rio Blanco 1/	100	300	400	300	300	300	300
B. Spring wheat							
Moffat	1,000	1,000	500	300	300	600	1,000
Routt	--	--	--	--	--	--	--
Rio Blanco	--	--	--	--	--	--	--
C. Corn (grain)							
Moffat	200	--	--	100	--	--	--
Routt	200	100	--	--	--	--	--
Rio Blanco	100	200	--	100	--	--	--
D. Barley							
Moffat	200	100	100	100	200	100	100
Routt	500	200	500	300	400	200	200
Rio Blanco	300	100	100	300	200	100	100
E. Alfalfa							
Moffat	9,000	7,000	7,500	8,000	8,000	7,200	10,000
Routt	4,000	4,400	4,800	4,200	4,400	5,000	6,700
Rio Blanco	6,100	6,000	6,600	5,000	6,400	3,700	7,600
F. Other hay (harvested)							
Moffat	6,300	9,000	9,300	10,000	11,000	12,000	9,600
Routt	32,000	28,000	25,000	31,000	31,000	36,000	26,000
Rio Blanco	15,500	15,000	13,500	14,000	15,800	13,000	17,500
G. Oats							
Moffat	300	300	100	300	200	--	100
Routt	200	300	--	500	200	600	400
Rio Blanco	300	200	100	200	300	300	20
River Basin ~~Total irrigated~~ acreage without pasture			***				
Yampa	54,800	52,100	49,400	55,500	56,400	61,800	
White	22,400	21,800	25,100	19,900			
F. Pasture							
Yampa	50,356	47,970	22,027	36,317	41,915	43,475	43,475
White							
Pasture consumptive use (1.0 AF/A)							
Yampa	50,356	47,970	22,027	36,317	41,915	43,475	
White	16,587	8,705	3,671	9,538	7,090	12,804	
Percentage of irrigated hay (irrigated/total) - alfalfa							Average
Yampa	52	51	56	57	55	60	55
White	87	88	94	70	88	55	80
Other hay							
Yampa	87	81	90	90	88	92	88
White	88	88	96	93	92	90	91

1/Moffat and Routt counties are in Yampa River basin and Rio Blanco in White River basi

Table A-21--Irrigation water consumptive use, selected crops, Yampa and White River basins, 1975-1980

River basin	1975	1976	1977	1978	1979	1980	1981
				A.F.			
A. All wheat (0.7)							
Yampa	1,330	1,890	1,470	700	700	910	
White	70	210	280	210	210	210	
B. Corn (grain) (1.1)							
Yampa	440	110	--	110	--	--	
White	110	220	--	110	--	--	
C. Barley (0.7)							
Yampa	490	210	420	280	420	210	
White	210	70	70	210	140	210	
D. Oats (0.7)							
Yampa	350	420	70	560	280	420	
White	210	140	70	140	210	210	
E. Alfalfa (1.5)							
Yampa	19,500	17,100	18,450	18,300	18,600	17,400	
White	9,150	9,000	9,900	7,500	9,600	5,550	
F. Other hay (1.3)							
Yampa	49,790	48,100	44,590	53,300	54,600	62,400	
White	20,150	19,500	17,550	18,200	20,540	16,900	
Total consumptive use (without pasture)							
Yampa	71,900	67,830	65,000	73,250	74,600	81,340	
White	29,900	29,140	27,870	26,370	30,700	23,080	
Total consumptive use							
Yampa	122,256	115,800	87,027	109,567	116,515	124,815	1/ 57,057
White	46,487	37,845	31,541	35,908	37,790	35,884	

1/ From Division 6 Water Budget Program.

The principal irrigated crops raised in both basins are: barley, winter wheat, alfalfa and mixed hay. Irrigated barley and wheat amounted to only 400 acres and 1,600 acres in 1980. The remainder was in hay production. Barley yields average 52 to 60 bushels per acre and winter wheat averages about 44 bushels per acre. Hay yields are about 1.7 to 2 tons per acre throughout the region. Irrigated agriculture in this area is not particularly intensive as reflected by the fairly low yields and estimated returns per acre shown in table A-22. Returns from irrigated crops are not high, and if charges were made for management costs and returns to land and equipment, net returns would be near zero or negative in many cases.

Irrigated agriculture is not intensive in this area (i.e., devoted to high value crops) because of the lack of late season irrigation water to serve most of the land. Stream flows drop to low levels in July, August and September. There are no large reservoirs to supply water for long season crops. Thus, the irrigated agriculture that has developed is primarily in support of cattle ranching, the major agricultural enterprise. The large area devoted to hay relative to other irrigated crops indicates the importance of winter feed supply to support cattle herds over the winter months.

An estimated 391,000 acre-feet of water were withdrawn in the Yampa Basin for irrigation of 112,000 acres. Average diversion was 3.55 A.F. per acre. In the White River Basin, the record shows, 322,000 acre-feet of water were diverted to irrigate 38,000 acres for an average diversion of 8.5 A.F. per acre. Even though these diversions appear adequate, most occur early in the crop season. It is not clear why diversions are greater on the White than the Yampa. Much of the water must be diverted untended onto the hay meadows. Actual evapotranspiration on hay and pasture ranges from 21 to 28 inches

Table A-22--Estimated yields, gross and net returns per acre from irrigated crops, Yampa River and White River basins, 1982 1/

Crop	Average yield/acre	Price per unit	Gross return per acre	Direct cash cost per acre	Net return per acre 2/
		- - - - - - -	Dollars	- - - - - - - -	
Irrigated hay	2.0 Ton	65.00	130.00	83.00	47.00
Barley	58.0 bu.	3.00	174.00	106.00	68.00
Winter wheat	44.0 bu.	3.35	147.40	106.00	41.40

1/ Yields, costs and returns are based on Colorado Agricultural Statistics and Farm Management Reports, Colorado Extension Service, Colorado State University, 1983.

2/ This does not include payment to management, return to land, or equipment, and depreciation.

during the April to October period with surface runoff and deep percolation accounting for the rest of the water applied to the land. Most of the irrigated land lies relatively close to the streams so that excess water returns rather quickly to the stream with little loss. Thus, while on-farm efficiencies are rather low, the losses incurred to the system through this process are relatively small.

With the low economic returns to agriculture, it is unlikely that the ranchers of northwest Colorado would be able to generate capital to upgrade irrigated cropping practices or improve the efficiency of their irrigation systems. Nor would the agricultural community be able to provide funding to develop reservoir storage for late season irrigation. Ranchers would not be able to add any large amount of capital investment to improve the irrigation systems. If investments were to be made in the irrigation systems of the region, it would probably be for providing reservoir storage to enhance late season water supply to improve hay production or to produce larger acreages of grain crops.

APPENDIX B

WATER SUPPLY AND USE FOR THE YAMPA, LITTLE SNAKE AND WHITE RIVER BASINS

WATER SUPPLY AND USE FOR THE
YAMPA, LITTLE SNAKE AND WHITE RIVER BASINS

	Yampa River at Maybell	Little Snake River at Lily Park	White River near Watson, Utah
Water Year 1972			
Drainage area, square mile	3,400	3,700	4,000
Irrigated acres	90,000	12,000	37,000
Irrigation diversions, A.F.	310,000	36,000	268,000
Municipal diversions, A.F.	4,600	--	--
Industrial diversions, A.F.	4,300	--	--
Transmountain diversions, A.F.	2,300	--	1,900
Estimated irrigation depletion, A.F. 1/	117,000	16,000	48,000
Estimated municipal depletion, A.F.	1,000	--	--
Estimated industrial depletion, A.F.	2,300	--	--
Change in reservoir storage, A.F.	- 1,800	--	+ 1,815
Surface outflow, A.F.	908,800	361,000	422,700
Basin yield, A.F.	1,029,800	2/ 377,000	473,915
Basin yield, A.F./ square mile	303	102	118

Source: Division Engineer, Division 6, State Engineer's Office, Colorado State Department of Water Resources.

1/ Estimated depletion figures on 25 percent consumptive use for all drainages.

2/ Basin yield does not reflect water consumed by Wyoming.

	Yampa River at Maybell	Little Snake River at Lily Park	White River ne[ar] Watson, Utah
Water Year 1973			
Drainage area, square mile	3,400	3,700	4,000
Estimated irrigated acres	90,000	12,000	37,000
Irrigation diversions, A.F.	270,000	39,000	280,000
Municipal diversions, A.F.	11,430	0	8,480
Industrial diversions, A.F.	5,270	0	7,590
Transmountain diversions, A.F.	2,780	0	0
Estimated irrigation depletion, A.F. 1/	67,500	9,750	70,000
Estimated municipal depletion, A.F.	1,000	0	500
Estimated industrial depletion, A.F.	2,000	0	7,000
Change in reservoir storage, A.F.	+ 1,092	+ 342	+ 418
Surface outflow, A.F.	1,232,000	519,000	566,000
Basin yield, A.F.	1,305,000	2/ 550,000	643,000
Basin yield, A.F./ square mile	384	149	161

1/ Estimated depletion figures on 25 percent consumptive use for all drainages.

2/ Basin yield for Little Snake estimated due to substantial amount of drainage being in Wyoming .

	Yampa River at Maybell	Little Snake River at Lily Park	White River near Watson, Utah
Water Year 1974			
Drainage area sq. mile	3,400	3,700	4,000
Estimated irrigated acres	98,800	11,300	36,500
Irrigation diversions, A.F.	356,120	35,708	322,150
Municipal diversions, A.F.	7,430	0	946
Industrial diversions, A.F.	4,920	0	7,590
Transmountain diversions, A.F.	750	0	0
Estimated irrigation depletion, A.F. 1/	89,030	0	80,540
Estimated municipal depletion, A.F.	1,500	0	190
Estimated industrial depletion, A.F.	2,470	0	7,590
Change in reservoir storage, A.F.	- 970	+ 649	+ 1,580
Surface outflow, A.F.	1,418,000	523,200	566,000
Basin yield, A.F.	1,510,780	2/ 523,849	655,900
Basin yield, A.F./ square mile	444	142	164

1/ Estimated depletion figures on 25 percent consumptive use for all drainages.
2/ Basin yield does not reflect water consumed by Wyoming.

APPENDIX C

APPENDIX C

Table C-1. Estimated consumptive use in the Yampa River basin, 1910-1977.

Use	1910	1911	1912	1913	1914	1915	1916	1917	1918	1919	1920	1921
							-Acre-feet-					
Irrigation depletion[1]	120,463	120,463	120,463	120,463	120,463	120,463	120,463	120,463	120,463	120,463	1020,463	120,463
Reservoir evaporation	0	0	0	0	0	0	0	0	0	0	0	0
Change in storage	0	0	0	0	0	0	0	0	0	0	0	0
Municipal - industrial	300	300	300	300	300	300	300	300	300	300	300	300
Transmountain	450	450	450	450	450	450	450	450	450	450	450	450
Miscellaneous	--	--	--	--	--	--	--	--	--	--	--	--
TOTAL	121,213	121,213	121,213	121,213	121,213	121,213	121,213	121,213	121,213	121,213	121,213	121,213
	1922	1923	1924	1925	1926	1927	1928	1929	1930	1931	1932	1933
Irrigation depletion	118,640	96,029	111,449	145,752	127,230	120,791	131,883	95,652	135,065	125,291	130,499	134,532
Reservoir evaporation	0	0	0	0	0	0	0	0	0	0	0	0
Change in storage	0	0	0	0	0	0	0	0	0	0	0	0
Municipal - industrial	300	300	300	300	300	300	300	300	300	300	300	300
Transmountain	450	450	450	450	450	450	450	450	450	450	450	450
Miscellaneous	--	--	--	--	--	--	--	--	--	--	--	--
TOTAL	119,390	96,774	112,199	146,502	127,980	121,541	132,633	96,402	135,815	126,041	131,249	135,282

[1]Use average of 55 years of record.

Table C-1 (Continued)

Use	1934	1935	1936	1937	1938	1939	1940	1941	1942	1943	1944	
	Acre-feet											
Irrigation depletion[1]	118,329	118,850	119,261	117,718	133,447	132,945	127,628	127,479	126,378	125,848	120,463	120,463
Reservoir evaporation	0	0	0	0	0	0	510	540	570	600	630	660
Change in storage	0	0	0	0	0	0	0	0	0	0	0	0
Municipal - industrial	300	300	300	300	300	300	300	300	300	300	300	300
Transmountain	450	450	450	450	450	450	450	500	600	700	800	900
Miscellaneous	--	--	--	--	--	--	--	--	--	--	--	--
TOTAL	119,079	119,600	120,011	118,468	134,197	133,695	128,888	128,819	127,848	127,448	122,193	122,323
	1946	1947	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957
Irrigation depletion	120,463	120,463	129,855	121,266	101,315	96,503	111,786	124,381	84,600	119,413	120,542	124,026
Reservoir evaporation	700	730	760	800	858	860	860	860	860	863	900	1,000
Change in storage	0	0	0	0	0	0	0	0	0	0	0	0
Municipal - industrial	300	300	400	400	500	400	400	400	400	400	400	400
Transmountain	1,000	1,100	1,200	1,300	1,500		1,500	1,500	1,500	1,500	1,700	1,700
Miscellaneous	--	--	--	--	--	--	--	--	--	--	--	--
TOTAL	122,463	122,593	132,215	123,766	104,273	99,263	114,546	127,141	87,360	122,176	123,542	127,126

[1] 1944 through 1947 use average of 55 years of record.

Table C-1 (Continued)

Use	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969
	Acre-feet											
Irrigation depletion	126,843	117,415	123,744	117,387	121,238	121,281	121,218	123,812	122,234	124,505	126,313	116,087
Reservoir evaporation	1,100	1,200	1,300	1,400	1,401	1,400	1,400	1,400	1,267	1,400	1,500	1,600
Change in storage	0	0	0	0	1,727	-4,800	-5,000	-2,244	-78	-6,500	-9,044	-8,000
Municipal - industrial	400	400	400	400	400	400	400	400	400	2,282	3,000	4,000
Transmountain	1,700	1,700	1,700	1,923	2,712	1,662	2,321	2,217	587	1,603	2,167	3,862
Miscellaneous	--	--	--	--	--	--	--	--	--	--	--	--
TOTAL	130,043	120,715	127,144	121,110	127,478	119,943	120,339	125,585	124,496	123,350	123,936	117,549
	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	
Irrigation depletion	121,761	132,508	125,477	125,728	127,434	122,256	115,800	87,027	109,567	116,515	124,815	
Reservoir evaporation	1,994	3,000	4,000	5,000	6,000	6,000	7,038	6,443	9,145	9,634	9,022	
Change in storage	3,780	-1,911	-1,800	1,092	-321	0	-9,071	-133	16,248	394	-1,465	
Municipal - industrial	4,925	5,000	3,560	6,680	4,928	5,000	7,100	6,200	6,900	9,900	11,800	
Transmountain	2,538	2,907	2,257	1,571	3,428	2,671	2,395	856	4,111	2,930	3,389	
Miscellaneous	--	--	--	--	--	--	16,750	750	1,000	950	800	
TOTAL	134,998	141,504	133,494	140,071	143,941	135,927	140,012	101,143	146,971	140,323	148,361	

Table C-2. Estimated consumptive use in the White River basin, 1922-1980.

Use	1922	1923	1924	1925	1926	1927	1928	1929	1930	1931	1932	1933
	Acre-feet											
Irrigation depletion			44,200	47,912	49,123	45,928	43,120	43,868	44,138	45,204	45,450	46,070
Reservoir evaporation			465	507	520	487	457	465	468	479	484	488
Change in storage			0	0	0	0	0	0	0	0	0	0
Municipal - industrial			1,861	2,030	2,081	1,946	1,828	1,859	1,871	1,916	1,935	1,952
Miscellaneous			300	300	300	300	300	300	300	300	300	300
TOTAL			46,526	50,749	52,024	48,661	45,705	46,493	46,777	47,899	48,368	48,811
	1934	1935	1936	1937	1938	1939	1940	1941	1942	1943	1944	1945
Irrigation depletion[1]	44,178	41,432	41,703	41,158	50,747	47,752	41,991	41,766	40,331	42,999	41,600	41,600
Reservoir evaporation	468	439	442	436	537	505	445	443	428	456	441	441
Change in storage	0	0	0	0	0	0	0	0	0	0	0	0
Municipal - industrial	1,873	1,757	1,768	1,746	2,149	2,023	1,781	1,771	1,710	1,823	1,764	1,764
Miscellaneous	300	300	300	300	300	300	300	300	300	300	300	300
TOTAL	46,819	34,928	44,214	43,640	53,734	50,581	44,517	44,280	42,769	45,578	44,105	44,105

[1]1944 through 1947 use average value of 52 years.

Table C-1 (Continued)

Use	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969
	---Acre-feet---											
Irrigation depletion	126,843	117,415	123,744	117,387	121,238	121,281	121,218	123,812	122,234	124,505	126,313	116,087
Reservoir evaporation	1,100	1,200	1,300	1,400	1,401	1,400	1,400	1,400	1,267	1,400	1,500	1,600
Change in storage	0	0	0	0	1,727	-4,800	-5,000	-2,244	-78	-6,500	-9,044	-8,000
Municipal - industrial	400	400	400	400	400	400	400	400	400	2,282	3,000	4,000
Transmountain	1,700	1,700	1,700	1,923	2,712	1,662	2,321	2,217	587	1,603	2,167	3,862
Miscellaneous	--	--	--	--	--	--	--	--	--	--	--	--
TOTAL	130,043	120,715	127,144	121,110	127,478	119,943	120,339	125,585	124,496	123,350	123,936	117,549
	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	
Irrigation depletion	121,761	132,508	125,477	125,728	127,434	122,256	115,800	87,027	109,567	116,515	124,815	
Reservoir evaporation	1,994	3,000	4,000	5,000	6,000	6,000	7,038	6,443	9,145	9,634	9,022	
Change in storage	3,780	-1,911	-1,800	1,092	-321	0	-9,071	-133	16,248	394	-1,465	
Municipal - industrial	4,925	5,000	3,560	6,680	4,928	5,000	7,100	6,200	6,900	9,900	11,800	
Transmountain	2,538	2,907	2,257	1,571	3,428	2,671	2,395	856	4,111	2,930	3,389	
Miscellaneous	--	--	--	--	--	--	16,750	750	1,000	950	800	
TOTAL	134,998	141,504	133,494	140,071	143,941	135,927	140,012	101,143	146,971	140,323	148,361	

Table C-2. Estimated consumptive use in the White River basin, 1922-1980.

Use	1922	1923	1924	1925	1926	1927	1928	1929	1930	1931	1932	1933
	-----	-----	-----	-----	-----	-Acre-feet-	-----	-----	-----	-----	-----	-----
Irrigation depletion			44,200	47,912	49,123	45,928	43,120	43,868	44,138	45,204	45,450	46,070
Reservoir evaporation			465	507	520	487	457	465	468	479	484	488
Change in storage			0	0	0	0	0	0	0	0	0	0
Municipal - industrial			1,861	2,030	2,081	1,946	1,828	1,859	1,871	1,916	1,935	1,952
Miscellaneous			300	300	300	300	300	300	300	300	300	300
TOTAL			46,526	50,749	52,024	48,661	45,705	46,493	46,777	47,899	48,368	48,811

	1934	1935	1936	1937	1938	1939	1940	1941	1942	1943	1944	1945
Irrigation depletion[1]	44,178	41,432	41,703	41,158	50,747	47,752	41,991	41,766	40,331	42,999	41,600	41,600
Reservoir evaporation	468	439	442	436	537	505	445	443	428	456	441	441
Change in storage	0	0	0	0	0	0	0	0	0	0	0	0
Municipal - industrial	1,873	1,757	1,768	1,746	2,149	2,023	1,781	1,771	1,710	1,823	1,764	1,764
Miscellaneous	300	300	300	300	300	300	300	300	300	300	300	300
TOTAL	46,819	3[illegible],928	44,214	43,640	53,734	50,581	44,517	44,280	42,769	45,578	44,105	44,105

[1] 1944 through 1947 use average value of 52 years.

Table C-2 (Continued)

Use	1946	1947	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957
	Acre-feet											
Irrigation depletion	41,600	41,600	42,818	42,231	40,704	37,527	40,327	40,504	40,379	39,461	36,132	37,919
Reservoir evaporation	441	441	454	448	432	398	428	430	428	418	484	402
Change in storage	0	0	0	0	0	0	0	0	0	0	0	0
Municipal - industrial	1,764	1,764	1,815	1,791	1,726	1,593	1,711	1,718	1,713	1,674	1,934	1,609
Miscellaneous	300	300	300	300	300	300	300	300	300	300	300	300
TOTAL	44,105	44,105	45,387	44,769	43,162	39,818	42,765	42,952	42,820	41,854	48,349	40,231
	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969
Irrigation depletion	36,672	35,641	48,104	39,785	45,927	43,085	43,244	35,140	36,301	36,420	39,328	37,752
Reservoir evaporation	389	378	509	1,169	1,347	1,265	1,269	1,034	1,067	1,071	1,155	1,109
Change in storage	0	0	0	0	0	0	0	0	0	0	0	0
Municipal - industrial	1,557	1,513	2,038	3,596	4,146	3,891	3,906	3,180	3,284	3,295	3,555	3,414
Miscellaneous	300	300	300	400	400	400	400	400	400	400	400	400
TOTAL	38,918	37,833	50,952	44,950	51,820	48,641	48,819	39,754	41,053	41,187	44,438	42,676

Table C-2 (Continued)

Use	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
	Acre-feet										
Irrigation depletion	44,229	46,555	43,124	45,358	38,219	46,487	37,845	31,541	35,908	37,790	35,884
Reservoir evaporation	1,298	1,413	1,309	1,317	1,162	1,411	1,170	1,322	1,178	1,140	1,120
Change in storage	0	0	0	0	0	0	-1,660	-147	-148	-76	123
Municipal - industrial	3,994	5,978	5,541	5,571	4,917	5,969	6,223	5,500	6,300	3,500	4,200
Miscellaneous	400	400	400	400	400	400	500	400	500	500	500
TOTAL	49,921	54,346	50,375	50,646	44,698	54,267	47,477	41,010	47,044	43,846	42,926

Notes: 1. Municipal-industrial consumptive use is average 11 percent and 8 percent of the total consumption during 1970-1980 and 1961-1970 respectively. Reservoir evaporation is 2.6 percent of the total.

2. 1961-1970 irrigation depletion averaged 89.4 percent. 1971-1980 irrigation depletion averaged 86.4 percent.

APPENDIX D

SUPPLEMENT TO RUN ANALYSIS FOR THE YAMPA RIVER

APPENDIX D. Supplement to Run Analysis for the Yampa River

This analysis was made with the basic assumption that the required amount of at least 5 million acre-feet that was to be delivered downstream from Maybell, Colorado, in any ten consecutive years as stated in the 1948 interstate compact was evenly distributed over each year (i.e., 500,000 acre-feet per year). It was felt it would be worthwhile to study this beyond-the-safe-side case since the mean annual runoff of 1,050,000 acre-feet at Maybell is over the average 500,000 acre-feet requirement. Needless to say, this assumption is unfavorable to water use in the upper Colorado since it would require 500,000 acre-feet every year and not a cumulative 5 million acre-feet every ten consecutive years. In the latter case, the 5 million acre-feet can be satisfied flexibly with the ten-year period.

Two alternative operational rules were assumed:

1) The 500,000 acre-feet downstream annual demand was considered to be satisfied in the non-irrigation period, which was the period from November through April. The remaining portion of this amount, if it was not previously satisfied, would be taken over to the irrigation period (May through October) and evenly distributed over the six months. Upstream demand was also taken into consideration. Two conditions under this alternative (which is referred to as Alternative #1) include: with and without additional storage capacity. The statistical results of the run analysis are listed in Table E1.

Take the existing condition as an example. If, in the case of no additional storage, 904 runs of deficit were to be reduced to 14 runs, and the corresponding depletion of 414,554 acre-feet were to be reduced to 167,852 acre-feet, the additional storage needed would be

249,365 acre-feet. In the case of HWA (high level with accelerated energy development), 1,189 runs with a maximum depletion of 571,520 acre-feet could be reduced to 37 runs with a maximum depletion of 358,719 acre-feet if an additional storage of 408,671 acre-feet were made available.

2) The 500,000 acre-feet of downstream annual demand was to be satisfied in the non-irrigation period. The remaining part of this amount would be satisfied during the irrigation period using the excess water in the wet months to its utmost and not evenly distributed over the six months. This seemed to be a more reasonable approach since the excess water in the wet months was not wasted downstream as had been the case in Alternative #1. This scheme of operation was referred to as Alternative #2. The number of negative runs was reduced markedly to 69 for the existing condition as compared with Alternative #1. The 69 negative runs derived from considering only the upstream demand (without storage), which yielded 55 runs plus the negative runs obtained under the above operational rule, which yielded 14 runs. Actually, with the operation scheme, when additional storage was considered, the result was also 14 runs, which was also identical to the result obtained in Alternative #1 with additional storage. Table E2 gives the run statistics and Tables E3 through E9 show the number of runs against storage needed for the nine scenarios and the existing condition.

Table D-1. Yampa River run analysis, alternative #1.[1]

Level of Development	No. of Negative Runs		Average Months of Failure		Return Period (years)				Probability of Failure (%)				Storage Needed (ac-ft)
					Irrig. Period		Whole Year		Irrig. Period		Whole Year		
	Without Additional Storage	With Additional Storage	Without A.S.[2]	With A.S.	Without A.S.	With A.S.	Without A.S.	With A.S.	Without A.S.	With A.S.	Without A.S.	With A.S.	
Existing	904	14	922	14	0.54	34.7	1.08	71.4	15.37	0.24	7.68	0.12	249,365
LWO/LWB	974	17	1,013	17	0.49	29.4	0.98	58.8	16.88	0.28	8.44	0.14	276,066
LWA	1,029	18	1,091	18	0.46	27.8	0.92	55.5	18.18	0.30	9.09	0.15	301,567
MWO/MWB	1,075	19	1,150	19	0.43	26.3	0.87	52.6	19.16	0.32	9.58	0.15	325,868
MWA	1,130	24	1,220	24	0.41	20.8	0.82	41.7	20.34	0.40	10.17	0.20	355,769
HWO/HWB	1,138	32	1,229	32	0.40	15.6	0.81	31.3	20.48	0.54	10.24	0.27	378,270
HWA	1,189	37	1,308	37	0.38	13.5	0.77	27.0	21.80	0.62	10.90	0.31	408,671

[1]This alternative distributes the shortage of water in the non-irrigation period evenly to the 6 months in the irrigation period.

[2]A.S. = additional storage.

Table D-2. Yampa River run analysis, alternative #2.[1]

Level of Development	No. of Negative Runs		Average Months of Failure		Return Period (years)				Probability of Failure (%)				Storage Needed (ac-ft)
					Irrig. Period		Whole Year		Irrig. Period		Whole Year		
	Without Additional Storage	With Additional Storage	Without A.S.[2]	With A.S.	Without A.S.	With A.S.	Without A.S.	With A.S.	Without A.S.	With A.S.	Without A.S.	With A.S.	
Existing	69	14	89	14	5.7	34.7	11.3	71.4	1.48	0.24	0.74	0.12	167,852
LWO/LWB	113	17	162	17	3.1	29.4	6.2	58.8	2.70	0.28	1.35	0.14	199,893
LWA	148	18	212	18	2.3	27.8	4.7	55.5	3.54	0.30	1.77	0.15	230,495
MWO/MWB	174	19	256	19	1.8	26.3	3.9	52.6	4.26	0.32	2.13	0.16	259,576
MWA	210	24	317	24	1.6	20.8	3.2	41.7	5.28	0.40	2.64	0.20	295,457
HWO/HWB	215	32	327	32	1.5	15.6	3.1	31.3	5.48	0.50	2.73	0.27	322,238
HWA	264	37	401	37	1.2	13.5	2.5	27.0	6.68	0.62	3.34	0.31	358,719

[1]This alternative utilizes excess water in the irrigation period to its utmost.

[2]A.S. = additional storage.

Table D-3. Yampa River run analysis, alternative #2.

Level of Development: Existing

No. of Runs	Average Duration (months)	Storage Needed (acre-feet)
0	0	167,852
1	1	117,542
2	1	110,809
3	1	97,644
4	1	95,281
5	1	83,733
6	1	83,040
7	1	71,186
8	1	66,298
9	1	48,817
10	1	47,938
11	1	47,286
12	1	33,766
13	1	2,711
14	1	0

Table D-4. Yampa River run analysis, alternative #2.

Level of Development: LWO/LWB

No. of Runs	Average Duration (months)	Storage Needed (acre-feet)
0	0	199,893
1	1	149,583
2	1	142,850
3	1	129,685
4	1	127,322
5	1	115,774
6	1	115,081
7	1	103,227
8	1	98,339
9	1	80,858
10	1	79,979
11	1	79,327
12	1	79,327
13	1	34,752
14	1	31,317
15	1	6,702
16	1	1,036
17	1	0

Table D-5. Yampa River run analysis, alternative #2.

Level of Development: LWA

No. of Runs	Average Duration (months)	Storage Needed (acre-feet)
0	0	230,495
1	1	180,185
2	1	173,452
3	1	160,287
4	1	157,924
5	1	146,376
6	1	145,683
7	1	133,829
8	1	128,941
9	1	111,460
10	1	110,581
11	1	109,929
12	1	96,405
13	1	65,354
14	1	61,919
15	1	37,304
16	1	31,638
17	1	17,136
18	1	0

Table D-6. Yampa River run analysis, alternative #2.

Level of Development: MWO/MWB

No. of Runs	Average Duration (months)	Storage Needed (acre-feet)
0	0	259,576
1	1	209,266
2	1	202,533
3	1	189,368
4	1	187,005
5	1	175,457
6	1	174,464
7	1	162,910
8	1	158,022
9	1	140,541
10	1	139,662
11	1	139,010
12	1	125,490
13	1	94,435
14	1	91,000
15	1	66,385
16	1	60,719
17	1	46,217
18	1	11,622
19	1	0

Table D-7. Yampa River run analysis, alternative #2.

Level of Development: MWA

No. of Runs	Average Duration (months)	Storage Needed (acre-feet)
0	0	295,457
1	1	245,147
2	1	238,414
3	1	225,249
4	1	222,886
5	1	211,338
6	1	210,645
7	1	198,791
8	1	193,903
9	1	176,422
10	1	175,543
11	1	174,891
12	1	161,371
13	1	130,316
14	1	126,881
15	1	102,266
16	1	96,600
17	1	82,098
18	1	47,503
19	1	33,931
20	1	26,832
21	1	23,291
22	1	21,849
23	1	38
24	1	0

Table D-8. Yampa River run analysis, alternative #2.

Level of Development: HWO/HWB

No. of Runs	Average Duration (months)	Storage Needed (acre-feet)
0	0	322,238
1	1	271,928
2	1	265,195
3	1	252,030
4	1	249,667
5	1	238,119
6	1	237,426
7	1	225,572
8	1	220,684
9	1	203,203
10	1	202,324
11	1	201,672
12	1	188,152
13	1	157,097
14	1	153,662
15	1	129,047
16	1	123,381
17	1	108,879
18	1	74,284
19	1	60,712
20	1	53,613
21	1	50,072
22	1	48,630
23	1	26,819
24	1	25,580
25	1	24,033
26	1	22,725
27	1	19,065
28	1	12,618
29	1	11,776
30	1	8,006
31	1	3,837
32	1	0

Table D-9. Yampa River run analysis, alternative #2.

Level of Development: HWA

No. of Runs	Average Duration (months)	Storage Needed (acre-feet)
0	0	358,719
1	1	308,409
2	1	301,676
3	1	288,511
4	1	286,148
5	1	274,600
6	1	273,907
7	1	262,053
8	1	257,165
9	1	239,684
10	1	238,805
11	1	238,153
12	1	224,633
13	1	193,578
14	1	190,143
15	1	165,528
16	1	159,862
17	1	145,360
18	1	110,765
19	1	97,193
20	1	90,094
21	1	86,533
22	1	85,111
23	1	63,309
24	1	62,061
25	1	60,514
26	1	59,206
27	1	55,546
28	1	49,099
29	1	48,257
30	1	44,487
31	1	40,318
32	1	35,640
33	1	31,882
34	1	27,266
35	1	21,713
36	1	18,656
37	1	0

APPENDIX E

YAMPA RIVER BASIN WATER RIGHTS (AMOUNT AND APPROPRIATION DATE) BASED ON "COLORADO WATER RIGHTS RETRIEVAL RUN USING THE CYBER COMPUTER"

APPENDIX E. Yampa River basin water rights (amount and appropriation date) based on "Colorado Water Rights Retrieval Run Using the Cyber Computer" (1879-1970).

Appropriation Date	Amount (c.f.s)	Cumulative Amount (c.f.s.)
1879	1.66	1.66
1881	38.92	40.58
1882	8.75	49.33
1883	79.6	128.93
1884	87.05	215.98
1885	29.89	245.87
1886	100.93	346.80
1887	229.08	575.88
1888	372.4	948.28
1889	186.27	1,134.55
1890	162.72	1,297.27
1891	54.18	1,351.45
1892	54.02	1,405.47
1893	64.20	1,469.67
1894	12.60	1,482.27
1895	73.32	1,555.59
1896	57.35	1,612.94
1897	27.1	1,640.04
1898	65.81	1,705.85
1899	43.94	1,749.79
1900	126.3	1,876.09
1901	72.3	1,948.39
1902	58.63	2,007.02
1903	209.47	2,216.49
1904	80.5	2,296.99
1905	39.76	2,336.75
1906	25.66	2,362.41
1907	51.79	2,414.2
1908	54.05	2,468.25
1909	56.18	2,524.43
1910	64.54	2,588.97
1911	26.15	2,615.12
1912	280.46	2,895.58
1913	73.26	2,968.84
1914	167.62	3,136.46
1915	101.39	3,237.85
1916	0.83	3,238.68
1917	3.78	3,242.46
1918	62.1	3,304.56
1919	51.17	3,355.73
1920	24.83	3,380.56
1921	57.96	3,438.52

APPENDIX E (Continued)

Appropriation Date	Amount (c.f.s)	Cumulative Amount (c.f.s.)
1922	23.91	3,462.43
1923	14.92	3,477.35
1924	8.11	3,485.46
1925	6.32	3,491.78
1926	35.61	3,527.39
1927	41.98	3,569.37
1928	29.14	3,598.51
1929	3.5	3,602.01
1930	24.1	3,626.11
1931	8.33	3,634.44
1932	15.0	3,649.44
1933	178.33	3,827.77
1934	32.85	3,860.62
1935	0.2	3,860.82
1936	4.81	3,865.63
1937	7.05	3,872.68
1938	23.3	3,895.98
1939	57.95	3,953.93
1940	19.8	3,973.73
1941	31.07	4,004.80
1942	5.25	4,010.05
1943	9.99	4,020.04
1944	6.90	4,026.94
1945	72.09	4,099.03
1946	97.18	4,196.21
1947	14.55	4,210.76
1948	49.0	4,259.76
1949	25.84	4,285.60
1950	27.0	4,312.60
1951	114.97	4,427.57
1952	39.74	4,467.31
1953	33.21	4,500.52
1954	58.05	4,558.57
1955	68.7	4,627.27
1956	31.77	4,659.04
1957	33.6	4,692.64
1958	535.79	5,228.43
1959	26.89	5,255.32
1960	695.1	5,950.42
1961	140.73	6,091.15
1962	497.97	6,589.12
1963	1,856.05	8,445.17
1964	138.47	8,583.64
1965	27.09	8,610.73

APPENDIX E (Continued)

Appropriation Date	Amount (c.f.s)	Cumulative Amount (c.f.s.)
1966	8.87	8,619.60
1967	257.63	8,877.23
1968	31.32	8,908.55
1969	7.8	8,916.35
1970	5.0	8,921.35
TOTAL		8,921.35

APPENDIX E-1. Water rights filed by district, total CFS, reservoir rights, and acre-feet of rights of Water Districts 54, 55, 57, and 58, Yampa River Basin, Colorado.

Stream	Direct Flow Rights	Total CFS	Reservoir Rights	Total AF
Water District 54				
Little Snake River	39	154.737	--	--
Water District 55				
Little Snake River	19	230.81	--	--
Water District 57				
Yampa River	77	511.55	1	1,013.3
Fish Creek	18	560.76	3	72,408.8
West Br. Fish Creek	6	32.82	4	390.37
Middle Fish Creek	1	0.67	--	--
Water District 58				
Fish Creek	38	342.634	3	2,829.221
No. Fork Fish Creek	1	4.0	--	--
So. Fork Fish Creek	--	--	2	703.7
Middle Fork Fish Creek	2	180.00	2	2,350.86
Little Fish Creek	3	2.326	--	--
Elk River	87	283.3	1	44,038.7
No. Fork Elk River	2	302.5	--	--
Middle Fork Elk River	1	300.00	--	--
Soda Creek	30	103.077	3	33.63
Walton Creek	75	1,314.27	--	--
Watson Creek	24	47.93	6	895.26
Oak Creek	20	57.68	2	32.64
Hunt Creek	67	176.91	5	3,735.67
Bear Creek	2	1.33	--	--
Willow Creek	3	5.00	5	103,527.4
Reed Creek	5	5.35	--	--
Rock Creek	1	1.00	--	--
Big Creek	12	31.304	3	16.3
Mad Creek	5	99.77	1	5,712.00
Chimney Creek	10	16.09	--	--
Spring Creek	13	33.62	--	--
Yampa River	198	1,284.7368	10	152,470.7
Lawson Creek	12	23.362	1	25.6
Little Morrison Creek	10	14.14	--	--
Morrison Creek	13	19.97	1	5.62
Service Creek	6	663.00	1	22,000.00
Green Creek	3	7.39	2	48,229
Harrison Creek	3	128.00	--	--
Burgess Creek	12	17.9765	--	--
Beaver Creek	4	14.74	--	--

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CR 101	AN EMPIRICAL APPLICATION OF A MODEL FOR ESTIMATING THE RECREATION VALUE OF INSTREAM FLOW	Walsh, Ericson, Arosteguy, Hansen	10/80	4.00
CR 102	MEASURING BENEFITS AND THE ECONOMIC VALUE OF WATER IN RECREATION ON HIGH COUNTRY RESERVOIRS	Walsh, Aukerman, Milton	9/80	4.00
CR 103	EMPIRICAL APPLICATION OF A MODEL FOR ESTIMATING THE RECREATION VALUE OF WATER IN RESERVOIRS COMPARED TO INSTREAM FLOW	Walsh	12/80	4.00
IS 19	THE ENVIRONMENTAL QUALITY OBJECTIVE OF PRINCIPLES AND STANDARDS FOR PLANNING	McGinnis, Plott, Swanson	8/75	8.00

2. PLANNING/EVALUATION METHODOLOGY

a. Valuation (continued)

Report No.	Title	Author(s)	Date	Price
TR 14	ECONOMIC VALUE OF BENEFITS FROM RECREATION AT HIGH MOUNTAIN RESERVOIRS	Walsh, Aukerman, Rud	12/78	4.00
TR 24	THE SURVEY-BASED INPUT-OUTPUT MODEL AS A RESOURCE PLANNING TOOL	McKean	1/81	4.00
TR 44	DIRECT AND INDIRECT ECONOMIC EFFECTS OF HUNTING AND FISHING IN COLORADO - 1981	McKean, Nobe	1/84	5.00

b. System Simulation

Report No.	Title	Author(s)	Date	Price
CR 2	COMPUTER SIMULATION OF WASTE TRANSPORT IN GROUNDWATER AQUIFERS	Reddell, Sunada	6/69	3.00
CR 53	SYSTEMATIC DESIGN OF LEGAL REGULATIONS FOR OPTIMAL SURFACE-GROUNDWATER USAGE - PHASE I	Morel-Seytoux, Young, Radosevich	8/73	8.00
CR 62	FEASIBILITY AND POTENTIAL OF ENHANCING WATER RECREATION OPPORTUNITIES ON HIGH COUNTRY RESERVOIRS	Aukerman	6/75	5.00
CR 68	SYSTEMATIC DESIGN OF LEGAL REGULATIONS FOR OPTIMAL SURFACE-GROUNDWATER USAGE, PHASE 2	Morel-Seytoux	9/75	13.00
CR 82	DEVELOPMENT OF A SUBSURFACE HYDROLOGIC MODEL AND USE FOR INTEGRATED MANAGEMENT OF SURFACE AND SUBSURFACE WATER RESOURCES	Morel-Seytoux	12/77	4.00
CR 87	DEVELOPMENT OF A STREAM-AGUIFER MODEL SUITED FOR DEVELOPMENT	Morel-Seytoux	8/78	4.00
CR 89	SYNTHESIS AND CALIBRATION OF A RIVER BASIN WATER MANAGEMENT MODEL	Shafer, Labadie	10/78	4.00
CR 108	WATERLOGGING CONTROL FOR IMPROVED WATER AND LAND USE EFFICIENCIES: A SYSTEMATIC ANALYSIS	Simpson, Morel-Seytoux, Young	12/80	6.00
CR 112	DAILY OPERATIONAL TOOL FOR MAXIMUM BENEFICIAL USE MANAGEMENT OF SURFACE AND GROUNDWATERS IN A BASIN	Morel-Seytoux, Verdin, Illangasekare	3/82	4.00
CR 125	A RIVER BASIN NETWORK MODEL FOR CONJUNCTIVE USE OF SURFACE AND GROUNDWATER: PROGRAM CONSIM	Labadie, Phamwon, Lazaro	6.83	8.00
IS 33	THE IMPACTS OF IMPROVING EFFICIENCY OF IRRIGATION SYSTEMS ON WATER AVAILABILITY IN THE LOWER SOUTH PLATTE RIVER BASIN	Morel-Seytoux, Illangasekare, Bittinger, Evans	1/79	Free
TR 16	WATER MANAGEMENT MODEL FOR FRONT RANGE RIVER BASINS	Labadie, Shafer	4/79	6.00
TR 18	AN INTERACTIVE RIVER BASIN WATER MANAGEMENT MODEL: SYNTHESIS AND APPLICATION	Shafer	8/79	5.00
S-TB127	A SIMULATION MODEL FOR ANALYZING TIMBER-WATER JOINT PRODUCTION IN THE COLORADO ROCKIES		1975	1.25

A. WATER SUPPLY MANAGEMENT

2. PLANNING/EVALUATION METHODOLOGY

c. Analytical Models

Report No.	Title	Author(s)	Date	Price
CR 13	ECONOMICS OF GROUNDWATER DEVELOPMENT IN THE HIGH PLAINS OF COLORADO	Rohdy	6/69	2.50
CR 29	IDENTIFICATION OF URBAN WATERSHED UNITS USING REMOTE SPECTRAL SENSING	Root, Miller	6/71	6.00
CR 40	SELECTION OF TEST VARIABLE FOR MINIMAL TIME DETECTION OF BASIN RESPONSE TO NATURAL OR INDUCED CHANGES	Morel-Seytoux	12/72	4.00
CR 45	MATHEMATICAL MODELING OF WATER MANAGEMENT STRATEGIES IN URBANIZING RIVER BASINS	Walker, Skogerboe	6/73	8.50
CR 83	MODELLING THE DYNAMIC RESPONSE OF FLOODPLAINS TO URBANIZATION IN EASTERN NEW ENGLAND	Doehring, Smith	1/78	7.50
CR 90	MODELS FOR SYSTEM WATER PLANNING WITH SPECIAL REFERENCE TO WATER REUSE	Hendricks, Morel-Seytoux	6/78	6.00
CR 101	AN EMPIRICAL APPLICATION OF A MODEL FOR ESTIMATING THE RECREATION VALUE OF INSTREAM FLOW	Walsh, Ericson, Arosteguy, Hansen	10/80	4.00
CR 103	EMPIRICAL APPLICATION OF A MODEL FOR ESTIMATING THE RECREATION VALUE OF WATER IN RESERVOIRS COMPARED TO INSTREAM FLOW	Walsh	12/80	4.00
CR 108	WATERLOGGING CONTROL FOR IMPROVED WATER AND LAND USE EFFICIENCIES: A SYSTEMATIC ANALYSIS	Simpson, Morel-Seytoux, Young	12/80	6.00
CR 111	INVESTIGATION OF OBJECTIVE FUNCTIONS AND OPERATION RULES FOR STORAGE RESERVOIRS	Yevjevich, Hall, Salas	9/81	4.00
CR 114	PLANNING WATER REUSE: DEVELOPMENT OF REUSE THEORY AND THE INPUT-OUTPUT MODEL, VOL. I: FUNDAMENTALS	Turner, Hendricks	9.80	13.00
CR 115	PLANNING WATER REUSE: DEVELOPMENT OF REUSE THEORY AND THE INPUT-OUTPUT MODEL, VOL. II: APPLICATION	Klooz, Hendricks	9/80	6.00
CR 127	MATHEMATICAL MODELS FOR PREDICTION OF SOIL MOISTURE PROFILES	Morel-Seytoux	7/83	4.00
	OPTIMIZING CROP PRODUCTION THROUGH CONTROL OF WATER AND SALINITY LEVELS IN THE SOIL (Available through the Utah Water Research Center)	Stewart, Danielson, Hanks, Jackson, et.al.	9/77	
	PREDICTING CROP PRODUCTION AS RELATED TO DROUGHT STRESS UNDER IRRIGATION (Available through the Utah Water Research Center)	Hanks, Pruitt, Jackson, Danielson, et.al.	12/83	
IS 37	WATER FOR THE SOUTH PLATTE BASIN	Hendricks, Morel-Seytoux, Turner	3/79	Free
IS 40	PROCEEDINGS OF THE WORKSHOP ON INSTREAM FLOW HABITAT CRITERIA	Smith	12/79	6.00
IS 41	EXPLORING WAYS OF INCREASING THE USE OF SOUTH PLATTE WATER	Labadie, Shafer		Free
TR 8	MODELS DESIGNED TO EFFICIENTLY ALLOCATE IRRIGATION WATER USE BASED ON CROP RESPONSE TO SOIL MOISTURE STRESS	Anderson, Yaron, Young	5/77	5.00
TR 14	ECONOMIC VALUE OF BENEFITS FROM RECREATION AT HIGH MOUNTAIN RESERVOIRS	Aukerman, Rud	12/78	4.00
TR 20	DEVELOPMENT OF METHODOLOGIES FOR DETERMINING OPTIMAL WATER STORAGE STRATEGIES	Labadie, Fontane	9/80	3.00
TR 24	THE SURVEY-BASED INPUT-OUTPUT MODEL AS A RESOURCE PLANNING TOOL	McKean	1/81	4.00
TR 26	AN INPUT-OUTPUT ANALYSIS OF SPORTSMEN EXPENDITURES IN COLORADO	McKean	1/81	5.00

2. PLANNING/EVALUATION METHODOLOGY

c. Analytical Models (continued)

Report No.	Title	Author(s)	Date	Price
TR 34	ENERGY AND WATER SCARCITY AND THE IRRIGATED AGRICULTURAL ECONOMY OF THE COLORADO HIGH PLAINS: DIRECT ECONOMIC-HYDROLOGIC IMPACT FORECASTS (1979-2020)	Young, Conklin, Longenbaugh, Gardner	2/82	8.00
TR 44	DIRECT AND INDIRECT ECONOMIC EFFECTS OF HUNTING AND FISHING IN COLORADO	McKean, Nobe	1/84	5.00

d. Planning Procedure

Report No.	Title	Author(s)	Date	Price
TR 7	MANUAL FOR TRAINING IN THE APPLICATION OF PRINCIPLES AND STANDARDS (Water Resources Council)	Caulfield	12/74	11.00

3. DEMAND REDUCTION

Report No.	Title	Author(s)	Date	Price
CR 8	IMPROVING EFFICIENCY IN AGRICULTURAL WATER USE	Kemper, Danielson	6/69	2.00
CR 15	HYDRAULIC OPERATING CHARACTERISTICS OF LOW GRADIENT BORDER CHECKS IN THE MANAGEMENT OF IRRIGATION WATER	Heermann, Evans	6/68	4.00
CR 19	HYDRAULICS OF LOW GRADIENT BORDER IRRIGATION SYSTEMS	Evans, Heermann, Howe, Kincaid	6/70	4.00
CR 20	IMPROVING EFFICIENCY IN AGRICULTURAL WATER USE	Kemper	7/70	4.00
CR 25	EVAPORATION OF WATER AS RELATED TO WIND BARRIERS	Verma, Cermak	6/71	6.00
CR 41	GROUNDWATER RECHARGE AS AFFECTED BY SURFACE VEGETATION AND MANAGEMENT	Klute, Danielson, Linden, Hamaker	12/72	6.00
CR 49	IMPROVEMENTS IN MOVING SPRINKLER IRRIGATION SYSTEMS FOR CONSERVATION OF WATER	Miles	6/73	8.50
CR 52	CONSOLIDATION OF IRRIGATION SYSTEMS: PHASE I - ENGINEERING, LEGAL, AND SOCIOLOGICAL CONSTRAINTS AND/OR FACILITATORS	Skogerboe, Radosevich, Vlachos	6/73	25.00
CR 69	ENGINEERING AND ECOLOGICAL EVALUATION OF ANTITRANSPIRANTS FOR INCREASING RUNOFF IN COLORADO WATERSHEDS	Kreith	9/75	3.50
CR 80	ACHIEVING URBAN WATER CONSERVATION, A HANDBOOK	Flack, Weakley, Hill	9/77	7.00
CR 81	ACHIEVING URBAN WATER CONSERVATION: TESTING COMMUNITY ACCEPTANCE	Snodgrass, Hill	9/77	6.00
CR 94	CONSOLIDATION OF IRRIGATION SYSTEMS: PHASE II - ENGINEERING, ECONOMIC, LEGAL AND SOCIOLOGICAL REQUIREMENTS	Vlachos, Huszar, Radosevich, Skogerboe	5/80	9.00
CR 105	MUNICIPAL WATER USE IN NORTHERN COLORADO: DEVELOPMENT OF EFFICIENCY-OF-USE CRITERION	White, DiNatale, Greenberg, Flack	9/80	5.00
CR 106	URBAN LAWN IRRIGATION AND MANAGEMENT PRACTICES FOR WATER SAVING WITH MINIMUM EFFECT ON LAWN QUALITY	Danielson, Feldhake	5/81	7.00
CR 109	SALT- AND DROUGHT-TOLERANT CROP PLANTS FOR WATER CONSERVATION	Nabors	10/81	6.00
CR 120	THE EFFECTS OF WATER CONSERVATION ON NEW WATER SUPPLY FOR URBAN COLORADO UTILITIES	Ellinghouse, McCoy	12/82	9.00

Report No.	Title	Author(s)	Date	Price
	OPTIMIZING CROP PRODUCTION THROUGH CONTROL OF WATER AND SALINITY LEVELS IN THE SOIL (Available through the Utah Water Research Center)	Stewart, Danielson, Hanks, Jackson, et.al.	9/77	
	FACTORS INFLUENCING USEFULNESS OF ANTITRANSPIRANTS APPLIED ON PHREATOPHYTES TO INCREASE WATER SUPPLIES (Available through the California Water Resources Center)	Hagan, Kynard, Kreith, Anderson, et.al.	10/78	
	WATER REPORT FOR URBAN LAWNS (Available through the Wyoming Water Resources Center)		9/79	
	PREDICTING CROP PRODUCTION AS RELATED TO DROUGHT STRESS UNDER IRRIGATION (Available through the Utah Water Resources Center)	Hanks, Pruitt Jackson, Danielson, et.al.	12/83	
	WATER CONSERVATION INFORMATION DISSEMINATION DURING THE 1977 DROUGHT EMERGENCY (Available through the Utah Water Resources Center)		6/78	
IS 16	ANNOTATED BIBLIOGRAPHY ON TRICKLE IRRIGATION	Smith, Walker	6/75	Free
IS 26	WATER USE AND MANAGEMENT IN AN ARID REGION (Fort Collins, Colorado and Vicinity)	Anderson, DeRemer, Hall	9/77	6.00
IS 36	CUTTING CITY WATER DEMAND	Flack	5/79	Free
TR 8	MODELS DESIGNED TO EFFICIENTLY ALLOCATE IRRIGATION WATER USE BASED ON CROP RESPONSE TO SOIL MOISTURE STRESS	Anderson, Yaron, Young	5/77	5.00
TR 13	IMPACT ON IRRIGATION EFFICIENCY IMPROVEMENTS ON WATER AVAILABILITY IN THE SOUTH PLATTE RIVER BASIN	Bittinger, Danielson, Evans, Hart, Morel-Seytoux, Skinner	1/79	6.00
TR 28	AN ASSESSMENT OF WATER USE AND POLICIES IN NORTHERN COLORADO CITIES	DiNatale	3/81	6.00
S-TB128	EVALUATING WATER DISTRIBUTIONS OF SPRINKLER IRRIGATION SYSTEMS		1976	.85

4. SUPPLY AUGMENTATION

Report No.	Title	Author(s)	Date	Price
CR 3	SNOW ACCUMULATION IN RELATION TO FOREST CANOPY	Meiman, Froehlich, Dils	6/69	2.50
CR 9	CONTROLLED ACCUMULATION OF BLOWING SNOW	Rasmussen	6/69	3.50
CR 24	STUDIES OF THE ATMOSPHERIC WATER BALANCE	Rasmussen	8/71	6.00
CR 57	SNOW-AIR INTERACTIONS AND MANAGEMENT OF MOUNTAIN WATERSHED SNOWPACK	Meiman, Grant	6/74	4.00
CR 108	WATERLOGGING CONTROL FOR IMPROVED WATER AND LAND USE EFFICIENCIES: A SYSTEMATIC ANALYSIS	Simpson, Morel-Seytoux, Young	12/80	6.00
CR 114	PLANNING WATER REUSE: DEVELOPMENT OF REUSE THEORY AND THE INPUT-OUTPUT MODEL, VOL. I: FUNDAMENTALS	Turner, Hendricks	9/80	13.00
CR 115	PLANNING WATER REUSE: DEVELOPMENT OF REUSE THEORY AND THE INPUT-OUTPUT MODEL, VOL. II: APPLICATION	Klooz, Hendricks	9/80	6.00
CR 123	ARTIFICIAL GROUNDWATER RECHARGE, SAN LUIS VALLEY, COLORADO	Sunada	5/83	7.00
IS 32	SNOWPACK AUGMENTATION BY CLOUD SEEDING IN COLORADO AND UTAH	Chisholm, Grimes	8/79	5.00
IS 33	THE IMPACTS OF IMPROVING EFFICIENCY OF IRRIGATION SYSTEMS ON WATER AVAILABILITY IN THE LOWER SOUTH PLATTE RIVER BASIN	Morel-Seytoux, Illangasekare, Bittinger, Evans	1/79	Free

5. MANAGEMENT OF HYDROLOGIC EXTREMES

Report No.	Title	Author(s)	Date	Price
CR 10	ECONOMICS AND ADMINISTRATION OF WATER RESOURCES	Flack	6/69	3.50
CR 16	EXPERIMENTAL INVESTIGATION OF SMALL WATERSHED FLOODS	Smith, Yevjevich, Holland	6/68	3.00
CR 18	EXPERIMENTAL INVESTIGATION OF SMALL WATERSHED FLOODS	Schulz, Yevjevich	6/70	6.00
CR 56	EVALUATION AND IMPLEMENTATION OF URBAN DRAINAGE AND FLOOD CONTROL PROJECTS	Grigg, Rice, Bothan, Shoemaker	6/74	9.00
CR 65	URBAN DRAINAGE AND FLOOD CONTROL PROJECTS: ECONOMIC, LEGAL, AND FINANCIAL ASPECTS	Grigg, Tucker, Rice, Shoemaker	7/75	11.00
CR 85	DEVELOPMENT OF A DRAINAGE AND FLOOD CONTROL MANAGEMENT PROGRAM FOR URBANIZING COMMUNITIES - PART I	Riordan, Grigg, Hiller	9/78	3.00
CR 86	DEVELOPMENT OF A DRAINAGE AND FLOOD CONTROL MANAGEMENT PROGRAM FOR URBANIZING COMMUNITIES - PART II	Riordan, Grigg, Hiller	9/78	8.00
CR 95	DROUGHT-INDUCED PROBLEMS AND RESPONSES OF SMALL TOWNS AND RURAL WATER ENTITIES IN COLORADO: THE 1976-78 DROUGHT	Howe	6/80	5.00
CR 126	INCREASING THE ECONOMIC EFFICIENCY AND AFFORDABILITY OF STORM DRAINAGE PROJECTS	Cochrane, Huszar	9/83	4.00
	WATER CONSERVATION INFORMATION DISSEMINATION DURING THE 1977 DROUGHT EMERGENCY (Available through the Utah Water Resources Center)		6/78	
IS 13	FLOOD PLAIN MANAGEMENT OF THE CACHE LA POUDRE RIVER NEAR FORT COLLINS, COLORADO	Combs, McDonald, Martens, Rowe	8/74	3.75
IS 17	CACHE LA POUDRE RIVER NEAR FORT COLLINS, COLORADO - FLOOD MANAGEMENT ALTERNATIVES - RELOCATIONS AND LEVIES	Koirtyohann, Miller, Pope, Stein	8/75	6.00
IS 24	FACTORS AFFECTING PUBLIC ACCEPTANCE OF FLOOD INSURANCE IN LARIMER AND WELD COUNTIES, COLORADO	James, Kreger, Barrineau	9/77	4.00
IS 27	PROCEEDINGS, COLORADO DROUGHT WORKSHOPS		11/77	Free
IS 44	THE NATIONAL FLOOD INSURANCE PROGRAM IN LARIMER COUNTY, COLORADO AREA	Shoudy	8/80	4.00
S-GS856	RESEARCH DATA ASSEMBLY FOR SMALL WATERSHED FLOODS, PART II		1967	.50

6. RECREATION

Report No.	Title	Author(s)	Date	Price
CR 62	FEASIBILITY AND POTENTIAL OF ENHANCING WATER RECREATION OPPORTUNITIES ON HIGH COUNTRY RESERVOIRS	Aukerman	6/75	5.00
CR 78	SELECTING AND PLANNING HIGH COUNTRY RESERVOIRS FOR RECREATION WITHIN A MULTIPURPOSE MANAGEMENT FRAMEWORK	Aukerman, Carlson, Hiller, Labadie	7/77	7.00
CR 103	EMPIRICAL APPLICATION OF A MODEL FOR ESTIMATING THE RECREATION VALUE OF WATER IN RESERVOIRS COMPARED TO INSTREAM FLOW	Walsh	12/80	4.00
CR 124	EFFECTS OF WILDERNESS LEGISLATION ON WATER-PROJECT DEVELOPMENT IN COLORADO	Weaver	5/83	8.00
TR 3	IMPLEMENTATION OF THE FEDERAL WATER PROJECT RECREATION ACT IN COLORADO	Spence	6.74	Free
TR 11	FEDERAL WATER RECREATION IN COLORADO: COMPREHENSIVE VIEW AND ANALYSIS	Stefanec	5/78	6.00
TR 12	RECREATION BENEFITS OF WATER QUALITY: ROCKY MOUNTAIN NATIONAL PARK, SOUTH PLATTE RIVER BASIN, COLORADO	Walsh, Ericson, McKean, Young	5/78	5.00

B. WATER QUALITY

1. IDENTIFY AND CONTROL ENTERING POLLUTANTS

Report No.	Title	Author(s)	Date	Price
CR 14	HYDROGEOLOGY AND WATER QUALITY STUDIES IN THE CACHE LA POUDRE BASIN, COLORADO	Waltz	6/69	6.00
CR 21	WATERFOWL-WATER TEMPERATURE RELATIONS IN WINTER	Ryder	6/70	6.00
CR 54	GEOLOGIC FACTORS IN THE EVALUATION OF WATER POLLUTION POTENTIAL AT MOUNTAIN DWELLING SITES	Burns, McCrumb, Morrison	12/73	11.00
CR 60	RESEARCH NEEDS AS RELATED TO THE DEVELOPMENT OF SEDIMENT STANDARDS IN RIVERS	Gessler	3/75	4.00
CR 67	TOXIC HEAVY METALS IN GROUNDWATER OF A PORTION OF THE FRONT RANGE MINERAL BELT (Partial Report)	Edwards, Klusman	6/75	4.00
CR 71	SALT TRANSPORT IN SOIL PROFILES WITH APPLICATION TO IRRIGATION RETURN FLOW	Glas, McWhorter	1/76	6.00
CR 72	TOXIC HEAVY METALS IN GROUNDWATER OF A PORTION OF THE FRONT RANGE MINERAL BELT (Final Report)	Klusman, Edwards	6/76	5.00
CR 79	EVALUATION OF THE STORAGE OF DIFFUSE SOURCES OF SALINITY IN THE UPPER COLORADO RIVER BASIN	Laronne, Schumm	9/77	5.00
CR 84	POLLUTIONAL CHARACTERISTICS OF STORMWATER RUNOFF	Bennett, Linstedt	9/78	8.00
CR 104	DETECTION OF WATER QUALITY CHANGES THROUGH OPTIMAL TESTS AND RELIABILITY OF TESTS	Koch, Sanders, Morel-Seytoux	9/80	5.00
CR 107	ROLE OF SEDIMENT IN NON-POINT SOURCE SALT LOADING WITHIN THE UPPER COLORADO RIVER BASIN	Shen, Laronne, Enck, Sunday, Tanji, Whittig, Biggar	8/81	9.00
	SALINITY MANAGEMENT OPTIONS FOR THE COLORADO RIVER	Anderson, Kleinman	6/78	6.00
IS 25	SURVEILLANCE DATA, PLAINS SEGMENT OF THE CACHE LA POUDRE RIVER, COLORADO, 1970-1977	Morrison	1/78	6.00
IS 38	PUBLIC PARTICIPATION PRACTICES OF THE U.S. ARMY CORPS OF ENGINEERS	Crist, Lanier	7/79	4.00
S-GS870	CHEMICAL QUALITY OF GROUNDWATER IN THE PROSPECT VALLEY AREA, COLORADO		1968	.25

2. EFFECTS OF POLLUTANTS

Report No.	Title	Author(s)	Date	Price
CR 26	WATER TEMPERATURE AS A QUALITY FACTOR IN THE USE OF STREAMS AND RESERVOIRS	Ward, J.	12/71	4.00
CR 31	SEDIMENTATION AND CONTAMINANT CRITERIA FOR WATERSHED PLANNING AND MANAGEMENT	Shen	6/72	6.00
CR 73	PRODUCTION OF MUTANT PLANTS CONDUCIVE TO SALT TOLERANCE	Nabors	7/76	5.00
CR 96	THE PRODUCTION OF AGRICULTURALLY USEFUL MUTANT PLANTS WITH CHARACTERISTICS CONDUCIVE TO SALT TOLERANCE AND EFFICIENT WATER UTILIZATION	Nabors	10/79	4.00
CR 98	THE EFFECT OF ALGAL INHIBITORS ON HIGHER PLANT TISSUES	Kugrens	7/80	3.50
CR 116	EFFECTS OF RELEASES OF SEDIMENT FROM RESERVOIRS ON STREAM BIOTA	Ward, J.	9/82	4.00

B. WATER QUALITY

3. TREATMENT AND DISPOSAL OF WASTES

Report No.	Title	Author(s)	Date	Price
CR 1	BACTERIAL RESPONSE TO THE SOIL ENVIRONMENT	Boyd, Yoshida, Vereen, Cada, Morrison	6/69	4.50
CR 2	COMPUTER SIMULATION OF WASTE TRANSPORT IN GROUNDWATER AQUIFERS	Reddell, Sunada	6/69	3.00
CR 28	COMBINED COOLING AND BIO-TREATMENT OF BEET SUGAR FACTORY CONDENSER WATER EFFLUENT	Lof	6/71	6.00
CR 32	BACTERIAL MOVEMENT THROUGH FRACTURED BEDROCK	Morrison, Allen	7/72	6.00
CR 33	THE MECHANISM OF WASTE TREATMENT AT LOW TEMPERATURE, PART A: MICROBIOLOGY	Morrison, Newton, Boone, Martin	8/72	6.00
CR 34	THE MECHANISM OF WASTE TREATMENT AT LOW TEMPERATURE, PART B: SANITARY ENGINEERING	Ward, J., Hunter, Johansen	8/72	6.00
CR 59	A SYSTEM FOR GEOLOGIC EVALUATION OF POLLUTION AT MOUNTAIN DWELLING SITES	Waltz	1/75	4.50
CR 66	INDIVIDUAL HOME WASTEWATER CHARACTERIZATION AND TREATMENT	Bennett, Linstedt	7/75	9.00
CR 77	EVAPORATION OF WASTEWATER FROM MOUNTAIN CABINS	Ward, J.	3/77	9.00
CR 113	A WATER HANDBOOK FOR METAL MINING OPERATIONS	Wildeman	11/81	6.00
CR 121	SOLAR HEATING OF WASTEWATER STABILIZATION PONDS	Klemetson	3/83	5.00
IS 4	PROCEEDINGS, WORKSHOP ON HOME SEWAGE DISPOSAL IN COLORADO	Ward, R.	6/72	Free
IS 9	PROCEEDINGS OF THE SYMPOSIUM ON LAND TREATMENT AND SECONDARY EFFLUENT		11/73	4.00
IS 20	PROCEEDINGS, SECOND WORKSHOP ON HOME SEWAGE DISPOSAL IN COLORADO	Ward, R.	9/75	4.00
IS 29	PROCEEDINGS, THIRD WORKSHOP ON HOME SEWAGE DISPOSAL IN COLORADO - COMMUNITY MANAGEMENT	Ward, R.	7/78	5.00
IS 45	PROCEEDINGS, FOURTH WORKSHOP ON HOME SEWAGE DISPOSAL IN COLORADO - STATE/COUNTY COOPERATION IN MANAGING SMALL WASTEWATER FLOWS	Ward, R.	8/81	5.00
IS 49	PROCEEDINGS, FIFTH WORKSHOP ON HOME SEWAGE DISPOSAL IN COLORADO: OPERATION AND MAINTENANCE OF ON-SITE WASTEWATER TREATMENT SYSTEMS	Ward, R.	6/83	5.00
TR 10	EFFICIENCY OF WASTEWATER DISPOSAL IN MOUNTAIN AREAS	Walsh, Soper, Prato	1/78	6.00
TR 17	LAND TREATMENT OF MUNICIPAL SEWAGE EFFLUENT AT HAYDEN, COLORADO	Barbarick, Sabey, Evans	10/77	4.00

C. ECONOMIC IMPACTS

CR 10	ECONOMICS AND ADMINISTRATION OF WATER RESOURCES	Flack	6/69	3.50
CR 12	ECONOMICS AND ADMINISTRATION OF WATER RESOURCES	Nobe	6/69	4.00
CR 13	ECONOMICS OF GROUNDWATER DEVELOPMENT IN THE HIGH PLAINS OF COLORADO	Rohdy	6/69	2.50
CR 58	PRIMARY DATA ON ECONOMIC ACTIVITY AND WATER USE IN PROTOTYPE OIL SHALE DEVELOPMENT AREAS OF COLORADO: AN INITIAL INQUIRY	Gray	6/74	3.00
CR 65	URBAN DRAINAGE AND FLOOD CONTROL PROJECTS: ECONOMIC, LEGAL AND FINANCIAL ASPECTS	Grigg, Tucker, Rice, Shoemaker	7/75	11.00

C. ECONOMIC IMPACTS
(continued)

Report No.	Title	Author(s)	Date	Price
CR 70	AN ECONOMIC ANALYSIS OF WATER USE IN COLORADO'S ECONOMY	Gray	12/75	6.00
CR 75	PHYSICAL AND ECONOMIC EFFECTS ON THE LOCAL AGRICULTURAL ECONOMY OF WATER TRANSFER TO CITIES	Anderson, Wengert, Heil	10/76	4.00
CR 91	ECONOMIC BENEFITS FROM INSTREAM FLOW IN A COLORADO MOUNTAIN STREAM	Daubert, Young, Gray	6/79	6.00
CR 101	AN EMPIRICAL APPLICATION OF A MODEL FOR ESTIMATING THE RECREATION VALUE OF INSTREAM FLOW	Walsh, Erickson, Arosteguy, Hansen	10/80	4.00
CR 102	MEASURING BENEFITS AND THE ECONOMIC VALUE OF WATER IN RECREATION ON HIGH COUNTRY RESERVOIRS	Walsh, Aukerman, Milton	9/80	4.00
CR 118	ECONOMIC ASPECTS OF COST-SHARING ARRANGEMENTS FOR FEDERAL IRRIGATION PROJECTS: A CASE STUDY	Keleta, Young, Sparling	12/82	4.00
CR 122	ECONOMIC IMPACTS OF TRANSFERRING WATER FROM AGRICULTURE TO ALTERNATIVE USES IN COLORADO	Young	4/83	6.00
CR 126	INCREASING THE ECONOMIC EFFICIENCY AND AFFORDABILITY OF STORM DRAINAGE PROJECTS	Cochrane, Huszar	9/83	4.00
	SALINITY MANAGEMENT OPTIONS.... (Available from the Utah Water Resources Center)		6/78	
IS 2	ECONOMICS OF WATER QUALITY--SALINITY POLLUTION, Abridged Bibliography	Miller	6/71	12.00
IS 43	AN EVALUATION OF THE CACHE LA POUDRE WILD AND SCENIC RIVER DRAFT ENVIRONMENTAL IMPACT STATEMENT AND STUDY REPORT	Eubanks	8/80	6.00
TR 14	ECONOMIC VALUE OF BENEFITS FROM RECREATION AT HIGH MOUNTAIN RESERVOIRS	Walsh, Aukerman, Rud	12/78	4.00
TR 19	AN ECONOMIC EVALUATION OF THE GENERAL MANAGEMENT FOR YOSEMITE NATIONAL PARK	Walsh	3/80	5.00
TR 24	THE SURVEY-BASED INPUT-OUTPUT MODEL AS A RESOURCE PLANNING TOOL	McKean	1/81	4.00
TR 33	PROJECTED POPULATION, EMPLOYMENT, AND ECONOMIC OUTPUT IN COLORADO'S EASTERN HIGH PLAINS, 1979-2020	McKean	2/82	8.00
TR 34	ENERGY AND WATER SCARCITY AND THE IRRIGATED AGRICULTURAL ECONOMY OF THE COLORADO HIGH PLAINS: DIRECT ECONOMIC-HYDROLOGIC IMPACT FORECASTS (1979-2020)	Young, Conklin, Longenbaugh, Gardner	2/82	8.00
TR 44	DIRECT AND INDIRECT ECONOMIC EFFECTS OF HUNTING AND FISHING IN COLORADO - 1981	McKean, Nobe	1/84	5.00
S-545S	SECONDARY ECONOMIC EFFECTS OF IRRIGATION ON THE COLORADO HIGH PLAINS		1971	.80

D. ECOSYSTEM ISSUES

Report No.	Title	Author(s)	Date	Price
CR 5	SOIL MOVEMENT IN AN ALPINE AREA	Striffler	6/69	2.00
CR 69	ENGINEERING AND ECOLOGICAL EVALUATION OF ANTITRANSPIRANTS FOR INCREASING RUNOFF IN COLORADO WATERSHEDS	Kreith	9/75	3.50
CR 93	APPLICATION OF GEOMORPHIC PRINCIPLES TO ENVIRONMENTAL MANAGEMENT IN SEMIARID REGIONS	Schumm, Bradley, Begin	2/80	4.00
CR 98	THE EFFECT OF ALGAL INHIBITORS ON HIGHER PLANT TISSUES	Kugrens	7/80	3.50
CR 116	EFFECTS OF RELEASES OF SEDIMENT FROM RESERVOIRS ON STREAM BIOTA	Ward, J.V.	9/82	4.00

D. ECOSYSTEM ISSUES
(continued)

Report No.	Title	Author(s)	Date	Price
	FACTORS INFLUENCING USEFULNESS OF ANTITRANSPIRANTS APPLIED ON PHREATOPHYTES TO INCREASE WATER SUPPLIES (Available through the California Water Resources Center)	Hagan, Kynard, Kreith, Anderson, et.al.	10/78	
IS 7	WILDLIFE AND THE ENVIRONMENT, PROCEEDINGS OF THE GOVERNOR'S CONFERENCE, MARCH 1973 (Out of print--available through interlibrary loan)	Swanson	3/73	
IS 10	PROCEEDINGS, WORKSHOP ON REVEGETATION OF HIGH-ALTITUDE DISTURBED LANDS	Berg, Brown, Cuany	7/74	6.00
IS 11	SURFACE REHABILITATION OF LAND DISTURBANCES RESULTING FROM OIL SHALE DEVELOPMENT (Executive Summary)	Cook	6/74	Free
IS 14	BIBLIOGRAPHY PERTINENT TO DISTURBANCE AND REHABILITATION OF ALPINE AND SUBALPINE LANDS IN THE SOUTHERN ROCKY MOUNTAINS	Steen, Berg	2/75	4.00
IS 18	MINIMUM STREAM FLOWS AND LAKE LEVELS IN COLORADO	Rhinehart	8/75	9.00
IS 21	PROCEEDINGS, HIGH ALTITUDE REVEGETATION WORKSHOP NO. 2	Zuck, Brown	8/76	6.00
IS 28	PROCEEDINGS, HIGH ALTITUDE REVEGETATION WORKSHOP NO. 3	Kenny	6/78	6.00
IS 40	PROCEEDINGS OF THE WORKSHOP ON INSTREAM FLOW HABITAT CRITERIA	Smith	12/79	6.00
IS 42	PROCEEDINGS, HIGH ALTITUDE REVEGETATION WORKSHOP NO. 4	Jackson, Schuster	6/80	6.00
IS 48	PROCEEDINGS, HIGH ALTITUDE REVEGETATION WORKSHOP NO. 5	Cuany, Etra	12/82	6.00
TR 1	SURFACE REHABILITATION OF LAND DISTURBANCES RESULTING FROM OIL SHALE DEVELOPMENT	Cook	6/74	11.00
TR 4	VEGETATIVE STABILIZATION OF SPENT OIL SHALE	Harbert, Berg	12/74	4.00
TR 5	REVEGETATION OF DISTURBED SURFACE SOILS IN VARIOUS VEGETATION ECOSYSTEMS OF THE PICEANCE BASIN	Sims, Redente	12/74	5.25
TR 39	SPORTSMEN EXPENDITURES FOR HUNTING AND FISHING IN COLORADO, 1981	McKean, Nobe	1/83	5.00
TR 44	DIRECT AND INDIRECT ECONOMIC EFFECTS OF HUNTING AND FISHING IN COLORADO - 1981	McKean, Nobe	1/84	5.00
SR 2	ENVIRONMENT AND COLORADO - A HANDBOOK		1973	5.00

E. SOCIAL-INSTITUTIONAL-POLICY

1. INSTITUTIONS

Report No.	Title	Author(s)	Date	Price
CR 10	ECONOMICS AND ADMINISTRATION OF WATER RESOURCES	Flack	6/69	3.50
CR 12	ECONOMICS AND ADMINISTRATION OF WATER RESOURCES	Nobe	6/69	4.00
CR 36	URBAN-METROPOLITAN INSTITUTIONS FOR WATER PLANNING DEVELOPMENT AND MANAGEMENT: AN ANALYSIS OF USAGES OF THE TERM "INSTITUTIONS"	Wengert	9/72	6.00
CR 37	SEARCHING THE SOCIAL SCIENCE LITERATURE ON WATER: A GUIDE TO SELECTED INFORMATION STORAGE AND RETRIEVAL SYSTEMS - PRELIMINARY VERSION	Hogge, Wengert	9/72	6.00
CR 39	INSTITUTIONS FOR URBAN-METROPOLITAN WATER MANAGEMENT: ESSAYS IN SOCIAL THEORY	Wengert	11/72	6.00
CR 44	ECONOMIC, POLITICAL, AND LEGAL ASPECTS OF COLORADO WATER LAW	Radosevich, Nobe, Meek, Flack	2/73	6.00

E. SOCIAL-INSTITUTIONAL-POLICY

1. INSTITUTIONS (continued)

Report No.	Title	Author(s)	Date	Price
CR 46	EVALUATION OF URBAN WATER MANAGEMENT POLICIES IN THE DENVER METROPOLITAN AREA	Walker, Ward, R., Skogerboe	6/73	8.50
CR 47	COORDINATION OF AGRICULTURAL AND URBAN WATER QUALITY MANAGEMENT IN THE UTAH LAKE DRAINAGE AREA	Walker, Huntzinger, Skogerboe	6/73	8.50
CR 48	INSTITUTIONAL REQUIREMENTS FOR OPTIMAL WATER QUALITY MANAGEMENT IN ARID URBAN AREAS	Walker, Skogerboe, Ward, R., Huntzinger	6/73	4.00
CR 52	CONSOLIDATION OF IRRIGATION SYSTEMS: PHASE I - ENGINEERING, LEGAL, AND SOCIOLOGICAL CONSTRAINTS AND/OR FACILITATORS	Skogerboe, Radosevich, Vlachos	6/73	25.00
CR 53	SYSTEMATIC DESIGN OF LEGAL REGULATIONS FOR OPTIMAL SURFACE-GROUNDWATER USAGE - PHASE I	Morel-Seytoux, Young, Radosevich	8/73	8.00
CR 55	WATER LAW IN RELATION TO ENVIRONMENTAL QUALITY	Allardice, Radosevich, Koebel, Swanson	3/74	30.00
CR 61	ECONOMIC AND INSTITUTIONAL ANALYSIS OF COLORADO WATER QUALITY MANAGEMENT	Young, Radosevich, Gray, Leathers	3/75	6.00
CR 65	URBAN DRAINAGE AND FLOOD CONTROL PROJECTS: ECONOMIC, LEGAL AND FINANCIAL ASPECTS	Grigg, Tucker, Rice, Shoemaker	7/75	11.00
CR 75	PHYSICAL AND ECONOMIC EFFECTS ON THE LOCAL AGRICULTURAL ECONOMY OF WATER TRANSFER TO CITIES	Anderson, Wengert, Heil	10/76	4.00
CR 85	DEVELOPMENT OF A DRAINAGE AND FLOOD CONTROL MANAGEMENT PROGRAM FOR URBANIZING COMMUNITIES - PART I	Riordan, Grigg, Hiller	9/78	3.00
CR 86	DEVELOPMENT OF A DRAINAGE AND FLOOD CONTROL MANAGEMENT PROGRAM FOR URBANIZING COMMUNITIES - PART II	Riordan, Grigg, Hiller	9/78	8.00
CR 88	INSTITUTIONAL ARRANGEMENTS FOR EFFECTIVE WATER MANAGEMENT IN COLORADO	Foss	11/78	5.00
CR 94	CONSOLICATION OF IRRIGATION SYSTEMS: PHASE II, ENGINEERING, ECONOMIC, LEGAL AND SOCIOLOGICAL REQUIREMENTS	Vlachos, Huszar, Radosevich, Skogerboe	5/80	9.00
CR 118	ECONOMIC ASPECTS OF COST-SHARING ARRANGEMENTS FOR FEDERAL IRRIGATION PROJECTS: A CASE STUDY	Keleta, Young, Sparling	12/82	4.00
CR 124	EFFECTS OF WILDERNESS LEGISLATION ON WATER-PROJECT DEVELOPMENT IN COLORADO	Weaver	5/83	8.00
IS 6	WATER LAW AND ITS RELATIONSHIP TO ENVIRONMENTAL QUALITY: A BIBLIOGRAPHY OF SOURCE MATERIAL	Radosevich, Allardice, Swanson, Koebel	1/73	8.00
IS 12	WATER QUALITY CONTROL AND ADMINISTRATION LAWS AND REGULATIONS	Radosevich, Allen	1974	16.00
IS 15	PROCEEDINGS OF THE SYMPOSIUM ON WATER POLICIES ON U.S. IRRIGATED AGRICULTURE: ARE INCREASED ACREAGES NEEDED TO MEET DOMESTIC OR WORLD NEEDS?	Koelzer	3/75	5.00
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IS 34	SAN LUIS VALLEY WATER PROBLEMS: A LEGAL PERSPECTIVE	Radosevich, Rutz	1/79	5.00
IS 35	FEDERAL WATER STORAGE PROEJCTS: PLUSES AND MINUSES	Howe	6/79	Free
IS 39	ADMINISTRATION OF THE SMALL WATERSHED PROGRAM, 1955-1978, AN ANALYSIS	Fontenot	8/79	4.00
IS 45	PROCEEDINGS, FOURTH WORKSHOP ON HOME SEWAGE DISPOSAL IN COLORADO - STATE/COUNTY COOPERATION IN MANAGING SMALL WASTEWATER FLOWS	Ward, R.	8/81	5.00

E. SOCIAL-INSTITUTIONAL-POLICY

1. INSTITUTIONS (continued)

Report No.	Title	Author(s)	Date	Price
IS 46	THE DECLINING ROLE OF THE U.S. ARMY CORPS OF ENGINEERS IN THE DEVELOPMENT OF THE NATION'S WATER RESOURCES	Yoe	8/81	8.00
IS 49	PROCEEDINGS, FIFTH WORKSHOP ON HOME SEWAGE DISPOSAL IN COLORADO - OPERATION AND MAINTENANCE OF ON-SITE WASTEWATER TREATMENT SYSTEMS	Ward, R.	6/83	5.00
TR 3	IMPLEMENTATION OF THE FEDERAL WATER PROJECT RECREATION ACT IN COLORADO	Spence	6/74	Free
TR 9	THE 1972 FEDERAL WATER POLLUTION CONTROL ACT'S AREA-WIDE PLANNING PROVISION: HAS EXECUTIVE IMPLEMENTATION MET CONGRESSIONAL INTENT?	Stark	11/77	6.00
TR 11	FEDERAL WATER RECREATION IN COLORADO: COMPREHENSIVE VIEW AND ANALYSIS	Stefance	5/78	6.00
TR 31	COMMUNITY AND SOCIO-ECONOMIC ANALYSIS OF COLORADO'S HIGH PLAINS REGION	Burns	2/82	8.00
TR 38	GROUNDWATER QUALITY REGULATION IN COLORADO	Looft	12/82	6.00

2. PROCESSES

Report No.	Title	Author(s)	Date	Price
CR 11	ORGANIZATIONAL ADAPTATION TO CHANGE IN PUBLIC OBJECTIVES FOR WATER MANAGEMENT OF CACHE LA POUDRE RIVER SYSTEM	Hill, Foss, Meek	6/69	4.00
CR 17	AN EXPLORATION OF COMPONENTS AFFECTING AND LIMITING POLICYMAKING OPTIONS IN LOCAL WATER AGENCIES	Hill, Garrison, Foss	11/68	6.00
CR 22	AN EXPLORATION OF COMPONENTS AFFECTING AND LIMITING POLICYMAKING OPTIONS IN LOCAL WATER AGENCIES	Hill, Meek	6/70	4.00
CR 27	LOCAL WATER AGENCIES, COMMUNICATION PATTERNS, AND THE PLANNING PROCESS	Hill, Meek	9/71	6.00
CR 38	WATER QUALITY MANAGEMENT DECISIONS IN COLORADO	Nichols, Skogerboe, Ward, R.	6/72	6.00
CR 52	CONSOLIDATION OF IRRIGATION SYSTEMS: PHASE I - ENGINEERING, LEGAL, AND SOCIOLOGICAL CONSTRAINTS AND/OR FACILITATORS	Skogerboe, Radosevich, Vlachos	6/73	25.00
CR 65	URBAN DRAINAGE AND FLOOD CONTROL PROJECTS: ECONOMIC, LEGAL AND FINANCIAL ASPECTS	Grigg, Tucker, Rice, Shoemaker	7/75	11.00
CR 74	THE RELEVANCE OF TECHNOLOGICAL CHANGE IN LONG-TERM WATER RESOURCES PLANNING	Kraynick, Howe	10/76	4.50
CR 81	ACHIEVING URBAN WATER CONSERVATION: TESTING COMMUNITY ACCEPTANCE	Snodgrass, Hill	9/77	6.00
CR 94	CONSOLIDATION OF IRRIGATION SYSTEMS: PHASE II - ENGINEERING, LEGAL, AND SOCIOLOGICAL REQUIREMENTS	Vlachos, Huszar, Radosevich, Skogerboe	5/80	9.00
CR 95	DROUGHT-INDUCED PROBLEMS AND RESPONSES OF SMALL TOWNS AND RURAL WATER ENTITIES IN COLORADO: THE 1976-78 DROUGHT	Howe	6/80	5.00
CR 119	ECONOMIC ISSUES IN RESOLVING CONFLICTS IN WATER USE	Gray, Young	2/83	4.00
	WATER CONSERVATION INFORMATION DISSEMINATION DURING THE 1977 DROUGHT EMERGENCY (Available through the Utah WAter Resources Center)		6/78	
IS 22	IMPLEMENTATION OF THE NATIONAL FLOOD INSURANCE PROGRAM IN LARIMER COUNTY, COLORADO	Landenberger, Whittington	9/76	5.00
IS 24	FACTORS AFFECTING PUBLIC ACCEPTANCE OF FLOOD INSURANCE IN LARIMER AND WELD COUNTIES, COLORADO	James, Kreger, Barrineau	9/77	4.00

E. SOCIAL-INSTITUTIONAL-POLICY

2. PROCESSES (continued)

Report No.	Title	Author(s)	Date	Price
IS 27	PROCEEDINGS, COLORADO DROUGHT WORKSHOPS		11/77	Free
IS 38	PUBLIC PARTICIPATION PRACTICES OF THE U.S. ARMY CORPS OF ENGINEERS	Crist, Lanier	7/79	4.00
IS 44	THE NATIONAL FLOOD INSURANCE PROGRAM IN THE LARIMER COUNTY, COLORADO-AREA	Shoudy	8/80	4.00
IS 47	SECTION 404 OF THE CLEAN WATER ACT - AN EVALUATION OF THE ISSUES AND PERMIT PROGRAM IMPLEMENTATION IN WESTERN COLORADO	Barnett	8/82	6.00

F. WATER CONVEYANCE AND CONTROL WORKS

CR 6	STABILIZATION OF ALLUVIAL CHANNELS	Bhowmik, Simons	6/69	4.00
CR 7	STABILIZATION OF SLOPES WITH SEEPAGE	Muir, Simons	6/69	4.00
CR 111	INVESTIGATION OF OBJECTIVE FUNCTIONS AND OPERATION RULES FOR STORAGE RESERVOIRS	Yevjevich, Hall, Salas	9/81	4.00
IS 50	POSSIBLE CAPTURE OF THE MISSISSIPPI BY THE ATCHAFALAYA RIVER	Higby	8/83	5.00
SR 1	DESIGN OF WATER AND WASTEWATER SYSTEMS FOR RAPID GROWTH AREAS (Boom Towns, Mountain Resorts)	Flack	7/76	5.00
S-496S	FARM IRRIGATION STRUCTURES		1966	.50
S-522S	WEED SEED AND TRASH SCHEENS FOR IRRIGATION WATER		1966	.35
S-TB61	PARSHALL MEASURING FLUMES OF SMALL SIZES		1957	.25
S-TB120	SELECTION AND INSTALLATION OF CUTTHROAT FLUMES FOR MEASURING IRRIGATION AND DRAINAGE WATER		1976	3.50
S-TB126	A SHUNT-LINE METERING SYSTEM FOR IRRIGATION WELLS		1977	.75
X-426A	PARSHALL FLUMES OF LARGE SIZES		1961	.50

G. WATER DATA, PROJECTIONS, GENERAL INFORMATION

CR 37	SEARCHING THE SOCIAL SCIENCE LITERATURE ON WATER: A GUIDE TO SELECTED INFORMATION STORAGE AND RETRIEVAL SYSTEMS - PRELIMINARY VERSION	Hogge, Wengert	9/72	6.00
CR 46	EVALUATION OF URBAN WATER MANAGEMENT POLICIES IN THE DENVER METROPOLITAN AREA	Walker, Ward, R., Skogerboe	6/73	8.50
CR 60	RESEARCH NEEDS AS RELATED TO THE DEVELOPMENT OF SEDIMENT STANDARDS IN RIVERS	Gessler	3/75	4.00
CR 63	ANALYSIS OF COLORADO PRECIPITATION	Kuo, Cox	6/75	3.00
CR 100	A WATERSHED INFORMATION SYSTEM	Thomsen, Striffler	9/80	5.00
CR 113	A WATER HANDBOOK FOR METAL MINING OPERATIONS	Wildeman	11/81	6.00
	WATER CONSERVATION INFORMATION DISSEMINATION DURING THE 1977 DROUGHT EMERGENCY (Available through the Utah Water Resources Center)		6/78	

G. WATER DATA, PROJECTIONS, GENERAL INFORMATION
(continued)

Report No.	Title	Author(s)	Date	Price
IS 1	AN INVENTORY OF ENVIRONMENTAL RESOURCES RESEARCH IN PROGRESS		1/71	Free
IS 2	ECONOMICS OF WATER QUALITY - SALINITY POLLUTION, Abridged Bibliography	Miller	6/71	12.00
IS 3	AN INVENTORY OF ENVIRONMENTAL RESOURCES RESEARCH IN PROGRESS		7/72	Free
IS 5	DIRECTORY OF ENVIRONMENTAL RESEARCH FACULTY, CSU		12/72	Free
IS 8	INVENTORY OF CURRENT WATER RESOURCES RESEARCH AT CSU		7/73	Free
IS 23	INVENTORY OF COLORADO'S FRONT RANGE MOUNTAIN RESERVOIRS	Aukerman, Springer, Judge	5/77	6.00
IS 25	SURVEILLANCE DATA, PLAINS SEGMENT OF THE CACHE LA POUDRE RIVER, COLORADO	Morrison	1/78	6.00
IS 30	THE LARIMER-WELD COUNCIL OF GOVERNMENTS 208 WATER QUALITY PLAN: AN ASSESSMENT AND SUGGESTIONS FOR FUTURE DIRECTIONS	Bryniarski, Carter, Danley, Gurule	8/78	3.00
IS 31	THE DENVER BASIN: ITS BEDROCK AQUIFERS	Bittinger	1/79	Free
IS 34	SAN LUIS VALLEY WATER PROBLEMS: A LEGAL PERSPECTIVE	Radosevich, Rutz	1/79	5.00
IS 35	FEDERAL WATER STORAGE PROJECTS: PLUSES AND MINUSES	Howe	6/79	Free
IS 46	THE DECLINING ROLE OF THE U.S. ARMY CORPS OF ENGINEERS IN THE DEVELOPMENT OF THE NATION'S WATER RESOURCES	Yoe	8/81	8.00
IS 50	POSSIBLE CAPTURE OF THE MISSISSIPPI BY THE ATCHAFALAYA RIVER	Higby	8/83	5.00
TR 2	ESTIMATED AVERAGE ANNUAL WATER BALANCE FOR PICEANCE AND YELLOW CREEK WATERSHEDS	Wymore	8/74	Free
TR 6	COLORADO ENVIRONMENTAL DATA SYSTEMS (Abridged)	Whaley, Dyer	10/72	6.00
TR 12	RECREATION BENEFITS OF WATER QUALITY: ROCKY MOUNTAIN NATIONAL PARK, SOUTH PLATTE RIVER BASIN, COLORADO	Walsh, Ericson, McKean, Young	5/78	5.00
TR 21	THE ECONOMY OF ALBANY, CARBON, AND SWEETWATER COUNTIES, WYOMING - DESCRIPTION AND ANALYSIS	McKean, Weber	1/81	4.00
TR 22	AN INPUT-OUTPUT STUDY OF THE UPPER COLORADO MAIN STEM REGION OF WESTERN COLORADO	McKean, Weber	1/81	5.00
TR 23	THE ECONOMY OF MOFFAT, ROUTT, AND RIO BLANCO COUNTIES, COLORADO - DESCRIPTION AND ANALYSIS	McKean, Weber	1/81	5.00
TR 25	THE ECONOMY OF NORTHWESTERN COLORADO - DESCRIPTION AND ANALYSIS	Gray, McKean, Weber	1/81	5.00
TR 26	AN INPUT-OUTPUT ANALYSIS OF SPORTSMAN EXPENDITURES IN COLORADO	McKean	1/81	5.00
TR 27	AN INPUT-OUTPUT STUDY OF THE KREMMLING REGION OF WESTERN COLORADO	McKean, Weber	/81	4.00
TR 29	AN ECONOMIC INPUT-OUTPUT STUDY OF THE HIGH PLAINS REGION OF EASTERN COLORADO	McKean, Ericson Weber	2/82	8.00
TR 30	ENERGY PRODUCTION AND USE IN COLORADO'S HIGH PLAINS REGION	McBroom	2/82	8.00
TR 31	COMMUNITY AND SOCIO-ECONOMIC ANALYSIS OF COLORADO'S HIGH PLAINS REGION	Burns	2/82	8.00
TR 33	PROJECTED POPULATION, EMPLOYMENT, AND ECONOMIC OUTPUT IN COLORADO'S EASTERN HIGH PLAINS, 1979-2020	McKean	2/82	8.00
TR 34	ENERGY AND WATER SCARCITY AND THE IRRIGATED AGRICULTURAL ECONOMY OF THE COLORADO HIGH PLAINS: DIRECT ECONOMIC-HYDROLOGIC IMPACT FORECASTS (1979-2020)	Young, Conklin, Longenbaugh, Gardner	2/82	8.00
TR 35	THE ECONOMIES OF MESA COUNTY AND GARFIELD, MOFFAT, RIO BLANCO, AND ROUTT COUNTIES, COLORADO	McKean, Weber Ericson	4/81	5.00
TR 36	THE ECONOMY OF THE POWDER RIVER BASIN REGION OF EASTERN WYOMING: DESCRIPTION AND ANALYSIS	McKean, Weber Ericson	1/81	4.00

G. WATER DATA, PROJECTIONS, GENERAL INFORMATION (continued)

Report No.	Title	Author(s)	Date	Price
TR 37	AN INTERINDUSTRY ANALYSIS OF THREE FRONT RANGE FOOTHILLS COMMUNITIES: ESTES PARK, GILPIN COUNTY, AND WOODLAND PARK, COLORADO	McKean, Trock, Senf	7/82	6.00
TR 39	SPORTSMEN EXPENDITURES FOR HUNTING AND FISHING IN COLORADO, 1981	McKean, Nobe	1.83	5.00
TR 40	THE ECONOMY OF LINCOLN, SUBLETTE, SWEETWATER AND UINTA COUNTIES, WYOMING, ROCK SPRINGS BLM DISTRICT	McKean, Weber	5/83	5.00
TR 41	THE ECONOMY OF ALBANY, CARBON AND FREMONT COUNTIES, WYOMING, RAWLINS BLM DISTRICT	McKean, Weber	5/83	5.00
TR 42	THE ECONOMY OF BIG HORN, HOT SPRINGS, PARK, AND WASHAKIE COUNTIES, WYOMING, WORLAND BLM DISTRICT	McKean, Weber	5/83	5.00
TR 43	THE ECONOMY OF EASTERN WYOMING, CASPER BLM DISTRICT	McKean, Weber	5/83	5.00
SR 1	DESIGN OF WATER AND WASTEWATER SYSTEMS FOR RAPID GROWTH AREAS (Boom Towns, Mountain Resorts)	Flack	7/76	5.00
SR 3	IRRIGATION DEVELOPMENT POTENTIAL IN COLORADO	Whittlesey		5.00
SR 4	PICEANCE BASIN INVENTORY		12/71	11.00
SR 5	A GUIDE TO COLORADO WATER LAW	Fischer, Ray, Rask, Wyatt	9/78	3.50
S-GS870	CHEMICAL QUALITY OF GROUNDWATER IN THE PROSPECT VALLEY AREA, COLORADO		1968	.25
S-GS953	ECONOMIC ANALYSIS OF WATER USE IN BOULDER, LARIMER AND WELD COUNTIES, WITH PROJECTIONS TO 1980		1976	1.00
S-GS757	PUBLIC WATER SUPPLIES OF COLORADO, 1959-1960		1961	1.25
S-504S	COLORADO'S GROUNDWATER PROBLEMS		1967	.35
S-5125	GROUNDWATER IN THE BIJOU VALLEY		1961	.25
S-543S	PUMP IRRIGATION ON THE COLORADO HIGH PLAINS		1970	.65
X-470A	GROUNDWATER MANAGEMENT DISTRICT DIRECTOR'S HANDBOOK		1970	.25